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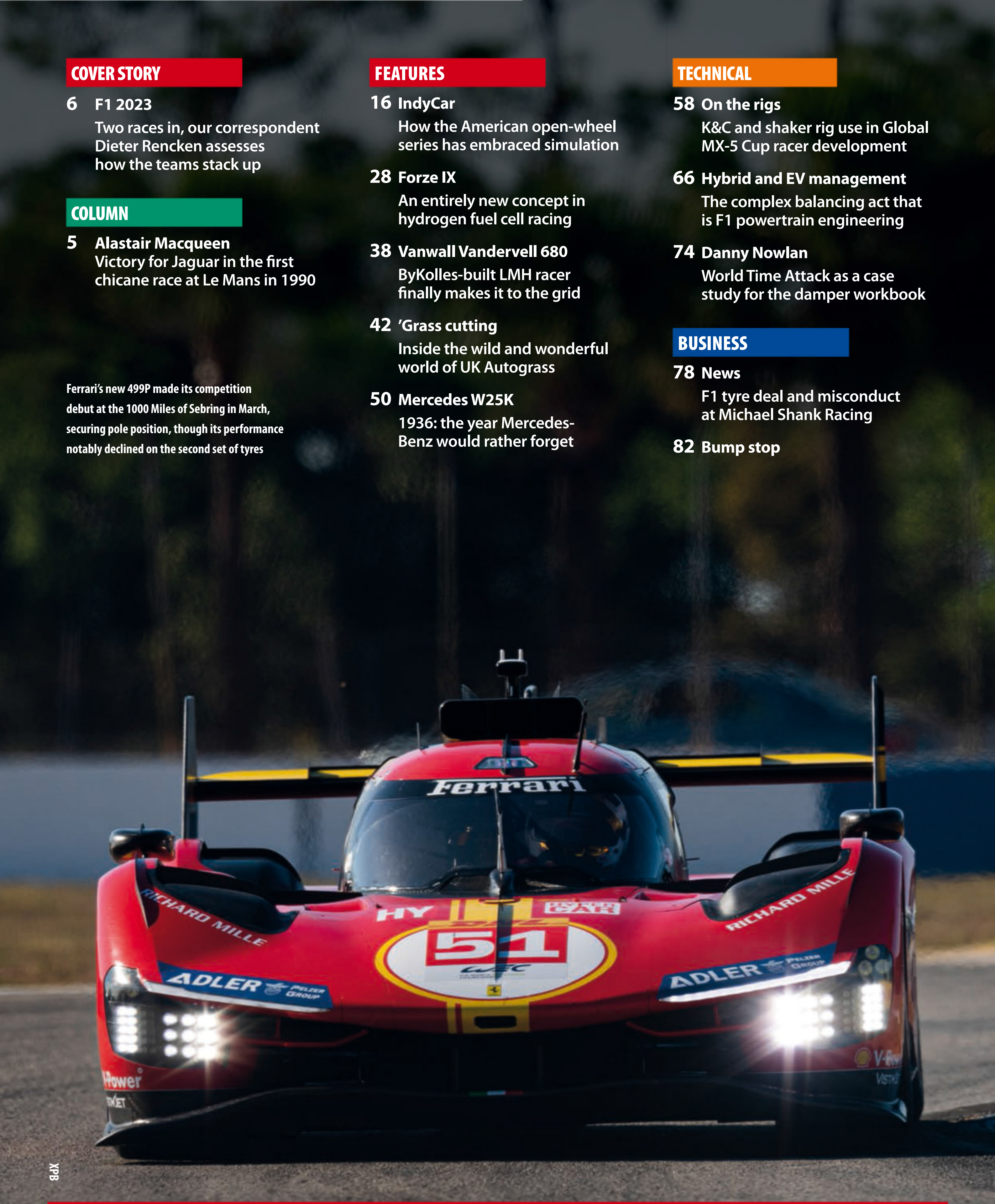

Ferrari's new 499P made its competition debut at the 1000 Miles of Sebring in March, securing pole position, though its performance notably declined on the second set of tyres

XPB

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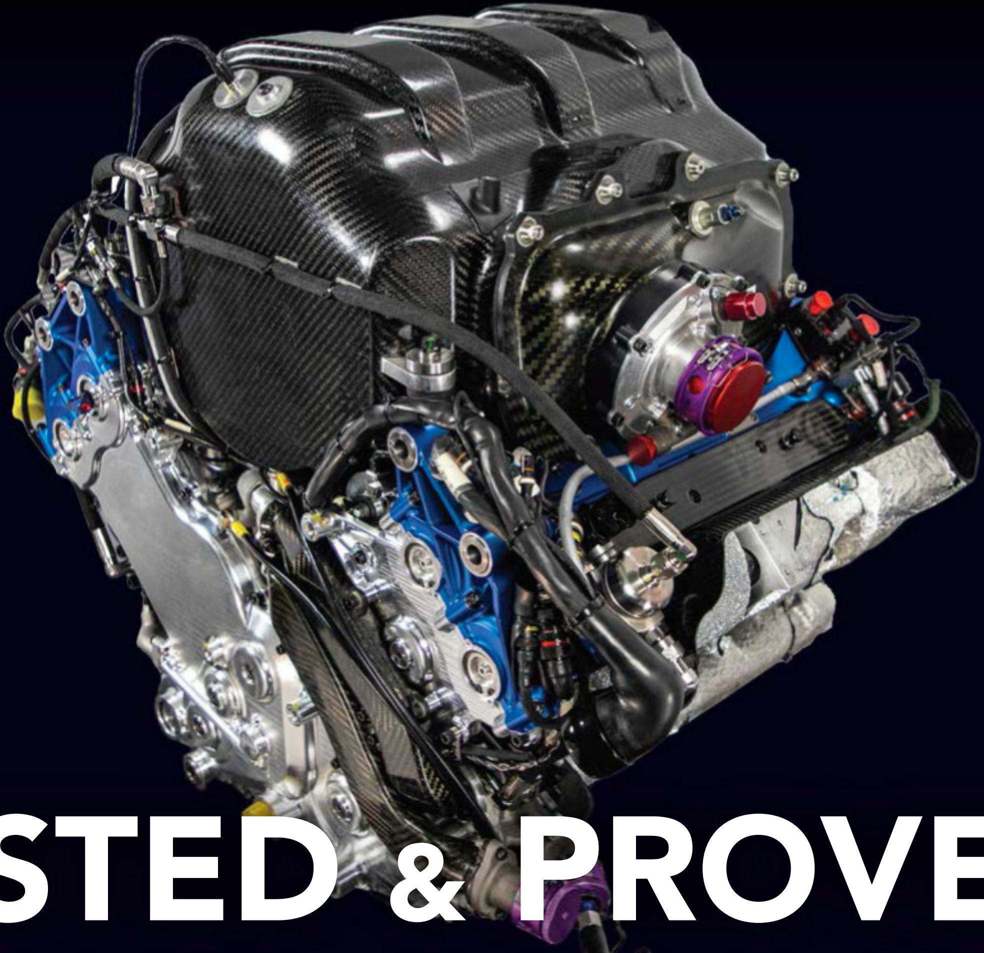

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Gambling man

Chicanes and redemption at Le Mans in 1990

I must confess that I have never actually worked in Formula 1. In fact, I've managed to stealthily avoid it all my life.

I was asked at the end of 1987 by Ross Brawn to race engineer for Arrows, but had to I say I still had unfinished business at Jaguar at that time, as we were yet to win at Le Mans.

In a quirk of fate, it was Ross who came to join me at TWR Jaguar at the start of 1990 as technical director and design a new 3.5-litre atmo' car for the new 1991 Group C regulations. We literally shared a desk for the first couple of months whilst his new design office was built, and in that time shared a great deal of information. Ross was generous enough to credit me in his book with his introduction to race strategy.

With Tony Southgate gone from the team and Ross busy with the design of his iconic XJR-14, it was down to me to develop a car to suit the 'new' circuit at Le Mans with two chicanes added into the Mulsanne straight.

I'd spent a couple of weeks in the Imperial College wind tunnel at the end of 1989 looking at the most efficient aerodynamics possible from this series of Jaguars with a 'medium' level of downforce. With none of the circuit and driver simulators we take for granted these days, development was very much a case of careful calculation and a dose of experience.

Without the need for a massive top speed, as in previous years, we would be running more downforce, going quicker in all the corners and inevitably running more drag… yet we weren't given an increase in the 2500-litre fuel allowance for the 24 hours.

Fortunately, I had the benefit of four years' running of cars at Le Mans by that stage and, crucially, the performance details of having run three very different downforce levels on my first visit to the circuit for the test day in '86.

Balancing act

I knew the car had to give the best aero efficiency ever, and that we would probably want a drag level similar to that run at Monza, but the big puzzle was where the aero balance should be. Most racecars typically run the aero 'split' at the same point as the c of g of the car. So, if you have a 40:60 weight distribution, you want the downforce to act in the same place to maintain balance throughout the speed range.

But the old Mulsanne straight, with its constant high speed on a truck-rutted public road would not tolerate this. A typical aero split on the old circuit was about 28-30 per cent.

After much debate, mostly with myself, I decided to centre the maximum efficiency around 38 per cent, reasoning that it is better to deal with a slight understeer at high speed than have the car trying to swap ends. On-circuit tuning aids would allow me to alter that by about +/-three per cent, with some loss of efficiency.

Adding NACA ducts in place of active scoop inlets was aiding the efficiency, but it was the position of the rear wing, to get the airflow from both the underside and topside of the car to combine effectively, which was the biggest step forward. I ended up using a two-piece wing with the main plane in a five degree nose-up attitude to match the flow regime off the tail, set at the optimum height and a distance back.

The lift-to-drag ratio on the low drag 1988 / '89 car was around 2.8. On the 1990 Le Mans car it was 4.0. Better even than on our high downforce 'sprint' cars.

3
Silk Cut
JAGUAR

The winning number three car, driven to victory at Le Mans in 1990 by John Nielsen, Price Cobb and Martin Brundle

One real positive was that Martin Brundle was back in the driver squad after playing with F1 cars in '89, and we had already won the Silverstone 1000kms together in the turbo car just prior to Le Mans. The two of us worked very well together.

When the first red flag came out during the first test session (to remove Jonathan Palmer's wrecked Porsche from the straight between the new chicanes) Martin comfortably topped the time sheets with the very minimum of adjustment and Jaguar went on to finish the first 'chicane' race in first and second positions. It was far from a flag-to-flag victory, though, battling with the Porsches, and seven Nissans. Two of the four Jaguars that started were sacrificed, and only in the final half hour was second place secured when a Porsche expired.

My number one car was one of the Jaguars to retire with overheating and eventual water pump failure, but the rules of the time said a driver could swap cars within the team, provided no more than three drivers drove the car in the race.

After my car pitted from the lead and lost four laps at about 8pm, Martin was rested until after midnight and was going to be put back in either car three or car one, depending on the position and state of the cars early in the morning. The overheating didn't go away on my car and it retired at 6am. Car three was still going well, so Martin joined John Nielsen and Price Cobb.

Using several sizes of angle we could clip on to the car half-way along the big side NACA duct to trip the flow into the oil coolers (an idea a borrowed from the cabin air intake duct on a Boeing 737), we were able to regulate the oil temperature and, together with Cobb, they drove the car to the finish. John drove 17 stints in that car, and Martin a total of 10 in the two cars.

This car was being run by our American IMSA squad who had fitted some very smart, American-made, billet, 'Fat Pad' calipers, which were claimed to reduce the number of pad stops during the race from three to two.

They worked really well and, by lunchtime on Sunday, the car was enjoying a two-lap cushion after just one pad change.

On the second change, one of the extra long caliper pistons seized and a new caliper had to be fitted, losing 1½ laps.

What was my Le Mans mantra again? Oh yes, if it's new, it will give a problem.

This was the Le Mans win I am most proud of and the one I contributed most to. We fought hard all the way for victory, even if I wasn't race engineering the winning car. Tired and happy, I fell to sleep face down in my dessert on Sunday evening having been awake for over 40 hours.

Tom was well pleased and 'rewarded' me with a new position heading up the development of the XJ220 at the end of the season. I learnt not to say no to Tom's requests.

So my last task that year in TWR Racing, after completing the Group C season, was to do the c of g calculations for Ross' XJR-14.

So, into the alien world of road cars I went.

With none of the circuit and driver simulators we take for granted these days, development was very much a case of careful calculation and a dose of experience

Same same, but *definitely* different

While the 2022-'23 regulations remained largely stable, there are four major changes: floor edges raised by 15mm; diffuser throat height raised; diffuser edge stiffness increased and and an additional sensor to monitor porpoising

After two races of the 2023 season, the Red Bull RB19, designed by Adrian Newey and his team, is class of the field, while the Aston Martin AMR, which bears close resemblance to the RB19, is its closest rival

With two rounds completed, Racecar *assesses how the 2023 F1 season is shaping up for each of the teams involved*

By DIETER RENCKEN

'Formula 1 cars all look the same. Paint each of them the same shade of white and you wouldn't be able to tell the difference…' is a criticism often heard of the sport's design direction. While perception is in the eye of the beholder, the overriding question is whether this is fact or fiction.

While a case could be made that the previous generation of 'top-down aerodynamics' F1 cars shared numerous common design elements, there is absolutely no doubt the pace-setting Red Bulls are as different from the Mercedes W14 as it is possible to be within the latest regulations, and it surely shows in terms of lap time.

Indeed, about the only commonality between cars this year is that their lower halves and certain sensitive components are presented in naked carbon to make individual differences harder to spot. If all the cars were the same, there would be no need to hide differentiators, for there would be none.

Equally, Ferrari (and customer Haas) chose a different concept, albeit one closer to the Red Bull philosophy than to the Silver Arrows. Again, it shows in terms of overall performance of the red cars, which could not be mistaken for that of either the blue or black-hued opposition.

After the first two races of the season run, there are absolutely no doubts that the Red Bull RB19, designed by Adrian Newey and his top-class team in Milton Keynes, is ahead of the field. Lewis Hamilton claims it to be ‘the fastest racecar I’ve ever seen.’ True, the Mercedes driver is regularly given hyperbole (and no doubt in search of reasons to justify his fall from the sharp end) but few drivers would disagree with his assessment.

Arguably, the biggest differences between various designs lies in their cooling systems – invisible beneath bodywork – which are variously split across sidepods and centreline heat exchangers. With four different power unit suppliers, each with unique turbo and hybrid units, and up to 13 different cooling systems per car to accommodate, it is little wonder no consensus exists, even where two or more teams draw from a common PU supplier.

One of 2022’s bugbears was the weight limit of 796kg, which teams battled to meet given the totally new regulations, plus stringent budget caps that discouraged the use of expensive but light materials. Add in substantial increases in downforce due to ground effects, and it was little wonder engineers erred on the side of caution, resulting in some cars being 10kg over the limit. Excesses have now largely been clawed back.

While the 2022-’23 regulations remained largely stable, there are four major changes: floor edges raised by 15mm; diffuser throat height raised; diffuser edge stiffness increased and and an additional mandated sensor to monitor porpoising.

These changes collectively created an estimated downforce loss equal to around 0.5 seconds per lap, so the primary task for all engineers was to claw back lost downforce, and then fine tune their packages to eke out lap time.

The opening rounds indicate that some managed better than others. How, then, does the class of 2023 stack up?

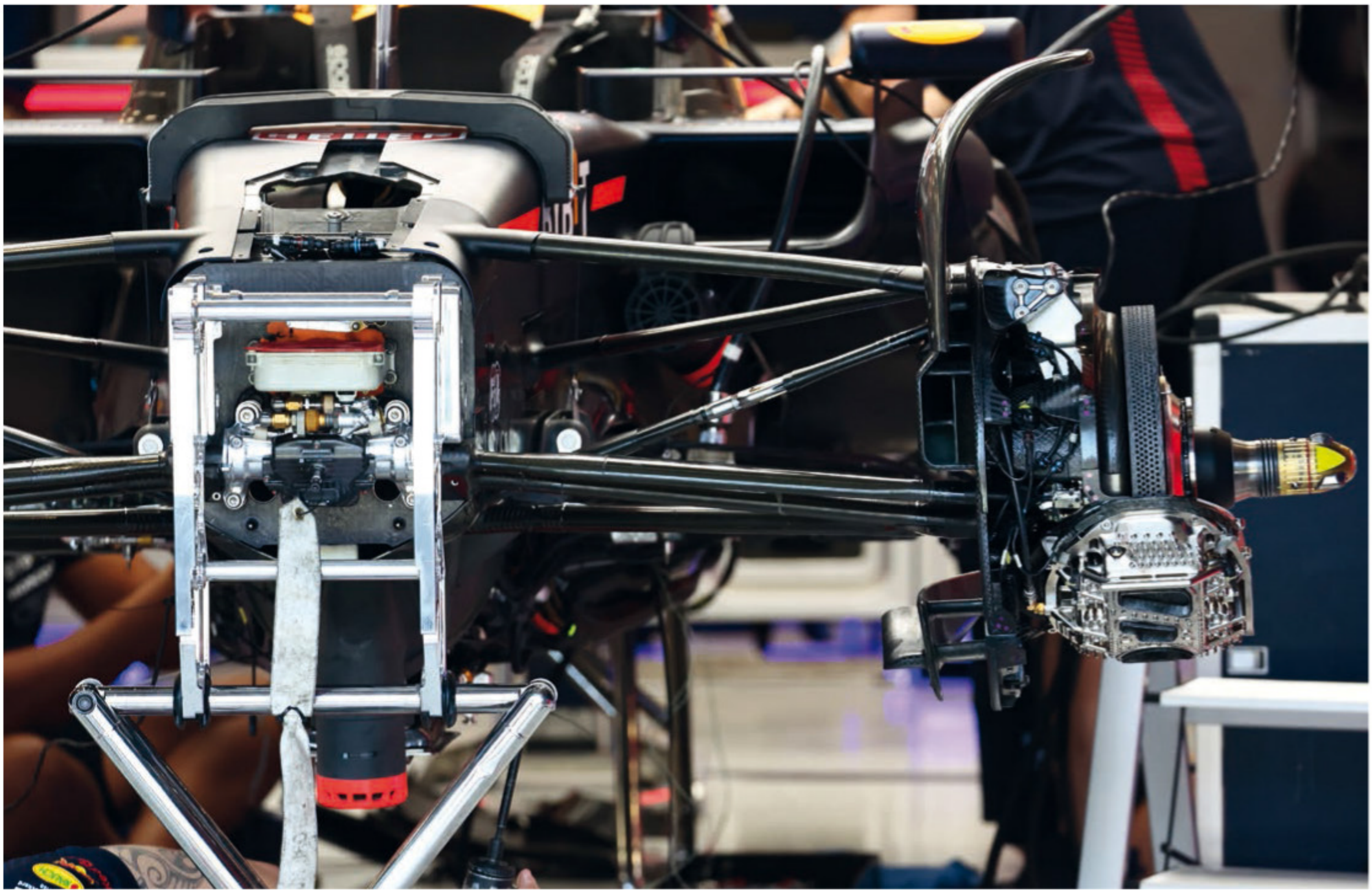
Red Bull RB19-Honda

As befits an evolution of the double-title-hauling RB18, this year’s car differs little from what went before it, on the surface at least. Look deeper, and it is clear the floor and inner sidepods of RB19 have been dramatically sculptured to generate even more ground effect ‘sticktion’ than its predecessor relied upon.

> **The floor and inner sidepods of RB19 have been dramatically sculptured to generate even more ground effect ‘sticktion’ than its predecessor relied upon**

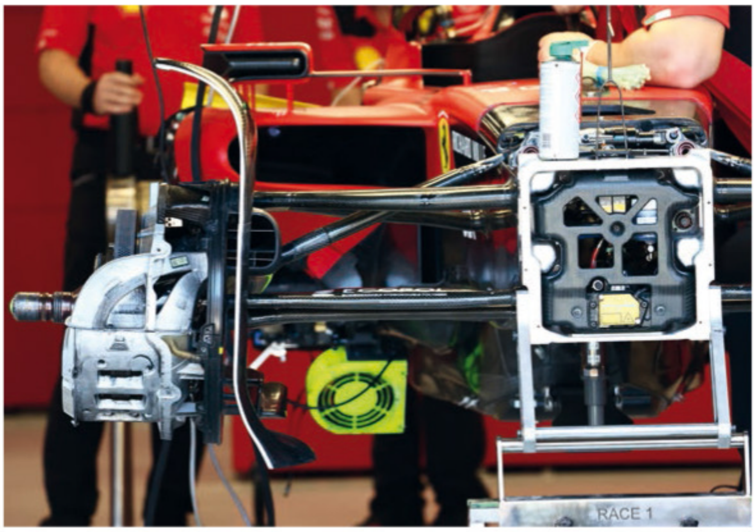
The secret with this generation of cars is to keep ride height not only as low as possible but perfectly stable, and RB19 excels by virtue of having steep front wishbone inclination that provides the anti-dive geometry, in turn creating a level platform better able to absorb the bouncing inherent in the current cars, even if by now in markedly reduced form.

RB19 is the least compromised design on the grid, having the best aerodynamic efficiency, cs of g and pressures – locating them in close proximity is crucial for benign tyre wear across all corners – and superb turn-in and rotational transition. Add in that Honda’s power unit provides the optimum mix of top-end performance, reliability,



The RB19 excels by virtue of having a steep front wishbone inclination, which provides anti-dive geometry, creating a level platform better able to absorb the bouncing inherent in current cars

Ferrari's 2023 F1 power unit is not proving to have the reliability the team needs to mount a serious fight for the championship



The Ferrari SF23 is noticeably 'snappier' than the rest and degrades its rear tyres faster, as attested to by driver, Carlos Sainz. This is a function of its front-end geometry

Ferrari's single-beam rear wing that flapped about alarmingly in Bahrain was strengthened considerably for Saudi by way of heavily beefed-up mountings

user-friendliness and hybrid deployment, and RB19 is a car that can't help winning.

If it has an Achilles Heel it is, as with many Newey designs, suspect reliability. This manifested itself during testing, and again during Bahrain practice / qualifying sessions (where re-designed engine plumbing was required), when a failed driveshaft scuppered Saudi qualifying for Max Verstappen. He complained of high-pitched vibrations during the race, which caused numerous heart stops for team management.

Ferrari SF23

Having ceased development of the F1-75 ahead of last year's summer break for budget cap reasons, Ferrari is desperately playing catch up with a car that has an inherent imbalance created by two distinct concepts: a single beam rear wing that flapped about alarmingly in Bahrain and was strengthened considerably for Saudi with beefed-up (25mm) mountings, and cs of g / pressure that are out of kilter.

The SF23 is noticeably 'snappier' than the rest and degrades its rear tyres faster, as attested to by Carlos Sainz who, after the Saudi race, laconically told *Racecar Engineering*, 'It's not the most stable car I've ever driven.'

That SF23 heats its rubber faster has been of little consolation, save during early stages of qualifying, when times hardly count.

Add in rumours of strife between Ferrari CEO, Benedetto Vigna, and incoming team principal, Frédéric Vasseur, (Mattia Binotto was unceremoniously forced out after last year) and woeful engine electronics issues (Charles Leclerc used up his season allocation of two ECUs in as many races), and it is little wonder Ferrari is already downbeat. Indeed, don't be surprised if more changes are effected soon. Again.

As things stand after Saudi, SF23 is the third fastest qualifier behind Red Bull and Aston Martin and fourth, possibly fifth, fastest after Mercedes.

Mercedes W14

In a nutshell, Mercedes faces the opposite situation to Ferrari in that it developed W13 through to the last race of last year. However, the problem is that despite having up to date data, the team was unable to switch concept due to the amount of time, money and effort invested in its (recalcitrant) 'zero sidepod' philosophy.

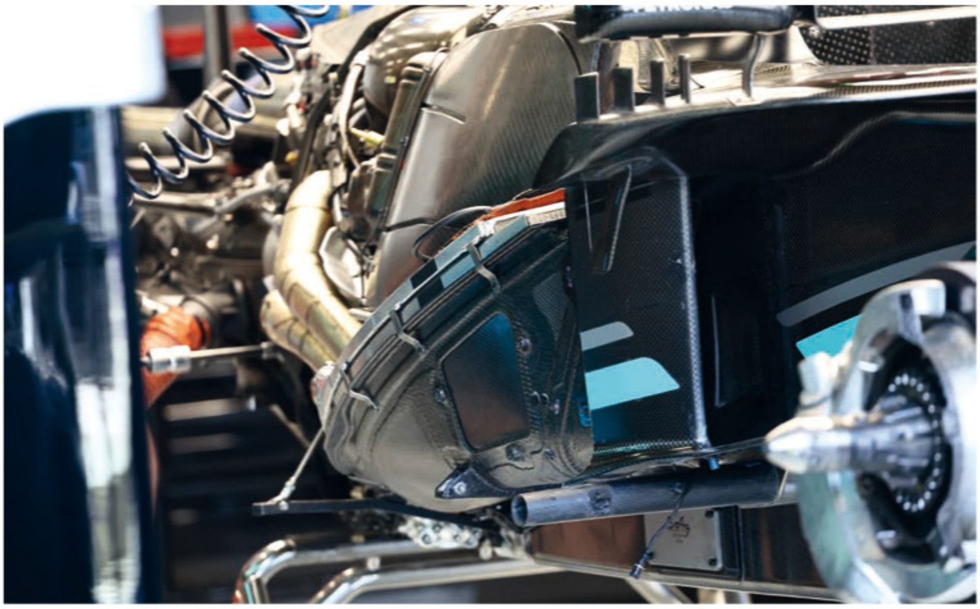
The bottom line is that the low-drag concept plateaued late last year, yet Mercedes engineers were determined to find performance improvements. Was it arrogant refusal to follow the lead of a 'fizzy drink special?' Ignorance about ground effects? Not invented here syndrome?

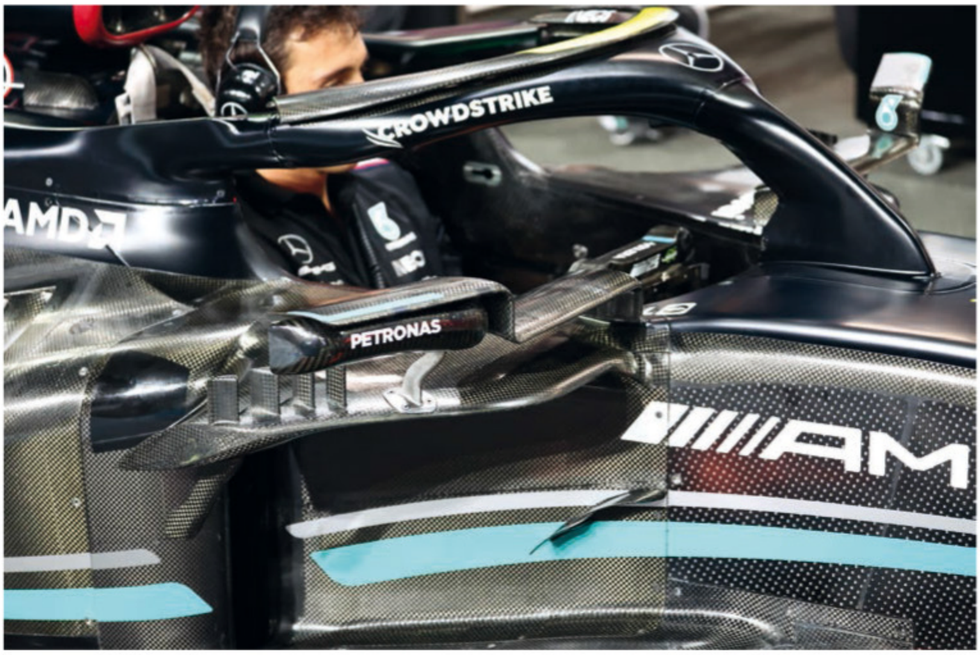
Whatever it was, driver, George Russell, told *Racecar Engineering* in Saudi Arabia that his (maiden) victory in Brazil towards the end of last season, at a time when final decisions re 2023's car were being taken, flattered to deceive by giving the team (false) hope that its W13 racecar was a winner, so they found no requirement for a change of design philosophy.

Coming to Bahrain testing and pre-race, the team was bullish, saying it had taken solid steps forward, but was quickly absolved of such notions come the event proper.

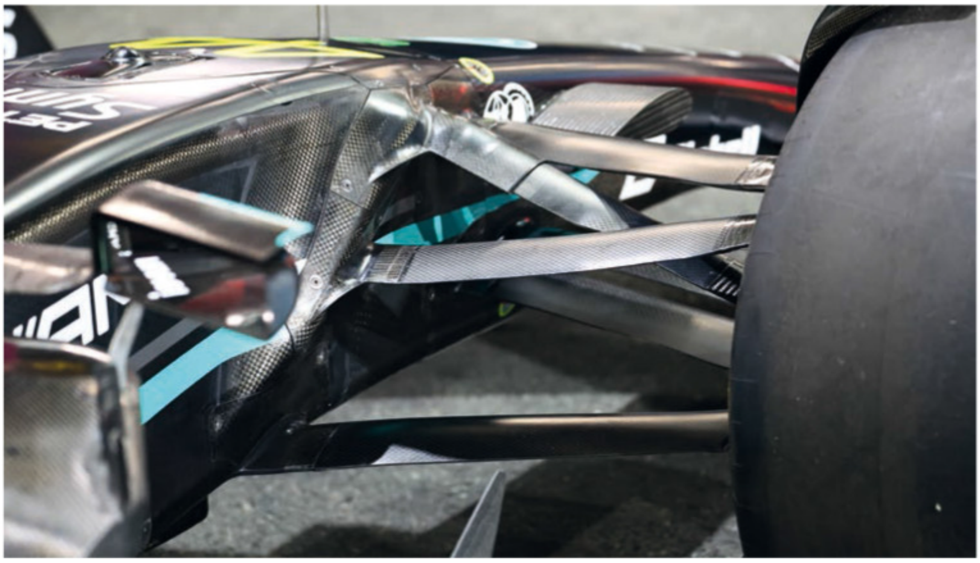
In Jeddah, team principal, Toto Wolff, spoke openly about the need for a wholesale revamp of the car, with all aerodynamic surfaces coming in for re-design, admitting that but for the budget cap Mercedes would be looking at a new chassis rather than simply revised bodywork.

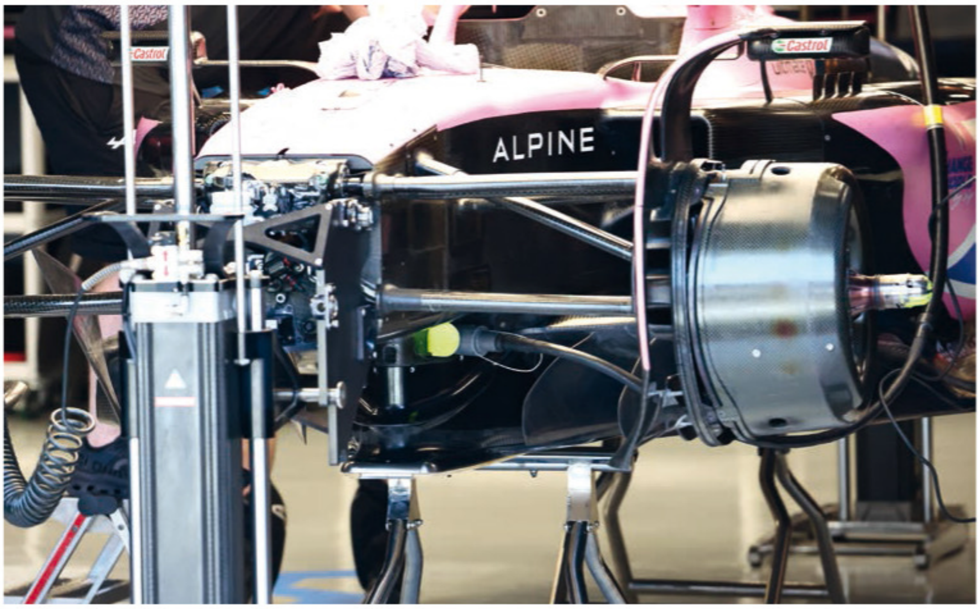
Without a change of chassis, W14B will still be heavily compromised on the sidepod front so, as per Scuderia Ferrari, 2023 seems a lost second season for this once-invincible outfit


Mercedes has carried over its low-drag, 'zero sidepod' concept from 2022, but it is now beginning to look increasingly outdated

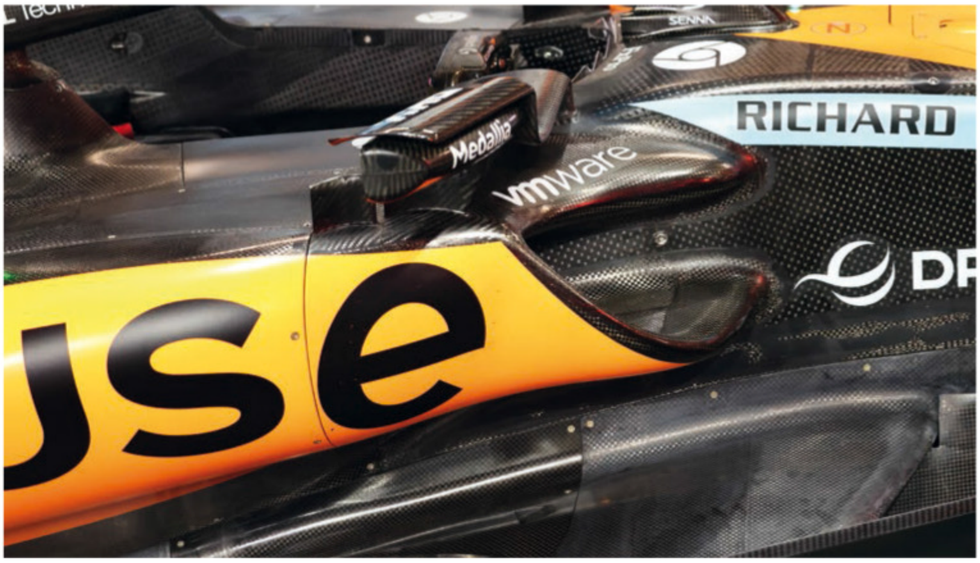


The German manufacturer spotted an opportunity in the new era rule set to design a wing around the upper side impact structure to add downwashing flow in that region of the car. The team has retained this feature on its 2023 challenger, too


Likewise, the W14's front suspension features downwashing bodywork where the wishbones interface with the nose of the car


The Renault F1 engine division's biggest challenge for 2023 is to amass sufficient data to resolve last season's unreliability issues

The 15mm floor edge raise from 2022 to 2023 seems to have had the biggest effect on McLaren, mostly due to its aerodynamic philosophies around this areas, and other inextricably linked details


The MCL60's sidepod intakes take inspiration from the Red Bull, with an extended lower lip to improve flow into the radiator inlet

'[The upgrade] won't be the same as other peoples, and it won't be the same as what we've got [now], said technical director, Mike Elliott, of the revised package, 'but it'll be different.'

Without a change of chassis, W14B will still be heavily compromised on the sidepod front so, as per Scuderia Ferrari, 2023 seems a lost second season for this once-invincible outfit.

Alpine A523-Renault

In evolving last year's A522, the French team's design and engineering duo of Pat Fry and Matt Harman again delivered an undramatic but solid midfield performer, based mainly on Red Bull sidepod philosophies. The car is indisputably fast in a straight line and has good turn-in, but seems to have a somewhat twitchy rear end, so is effectively a halfway house between Red Bull and Ferrari.

Although chief technical officer Fry believes the regulatory changes to the floor, 'probably stabilised the flow structures,' the A523 experiences unpredictable changes in balance – characteristics the drivers voiced across both race weekends.

After a huge effort on the weight front, Alpine managed to bring the car in under the weight limit, so much so that the team are now running ballast, which should help with set-up.

With no PU customers other than its in-house operation, the Renault F1 engine division's biggest challenge is to amass sufficient data to iron out the unreliability experienced last year. That factor, more than any other, will influence the team's overall performance.

McLaren-Mercedes MCL60

Two factors hamstring McLaren's current performance: the floor change, and the team's antiquated facilities in Woking, which force the aero department to travel to Toyota's Cologne facility for wind tunnel work – a major logistics challenge since Brexit. That said, a brand-new wind tunnel, upgraded CFD installations and a state-of-the-art simulator should be up and running later this year, having been delayed under Covid.

'The 15mm floor change doesn't sound like much,' explained former technical director, James Key, to *Racecar Engineering*, 'but for a ground-effect car it's significant. The effect doesn't appear to have been the same for all teams in terms of performance hit because of their front edge designs, so it's more to do with philosophies around things like floor edges, some of the profiles or tunnels, this sort of detail.

'If you had developed in a certain direction, you took a hit that you could recover quickly. With other directions, you took a bigger hit and had to completely re-think the car. Unfortunately, we're in the second camp.'

Sauber-Ferrari C43 (Alfa Romeo)

Most impressive of the midfield runners has been Sauber, which started last year on a fast but fragile footing, having engineered the C42 to the weight limit, but then paid the price in terms of unreliability. Consequently, quality processes were significantly beefed up, as were some cooling and electronics items.

Although technical director, Jan Monchaux, refused to be drawn of the extent of underbody changes, he did concede the car's mix of sidepod and centreline cooling (above the power unit, drawing air via the intake) had changed over C42 to increase sidepod ground effects.

Although C43 uses a complete Ferrari back end, the rest of the car is closer in philosophy to RB19 than SF23, and is therefore less 'snappy' and more predictable.

Tellingly, Monchaux is unbridled in his praise for the Red Bull team, saying the RB19 'is a strong source of inspiration' and that 'others would be short-sighted to not at least look into the concept. Tip of the hat to Red Bull.'

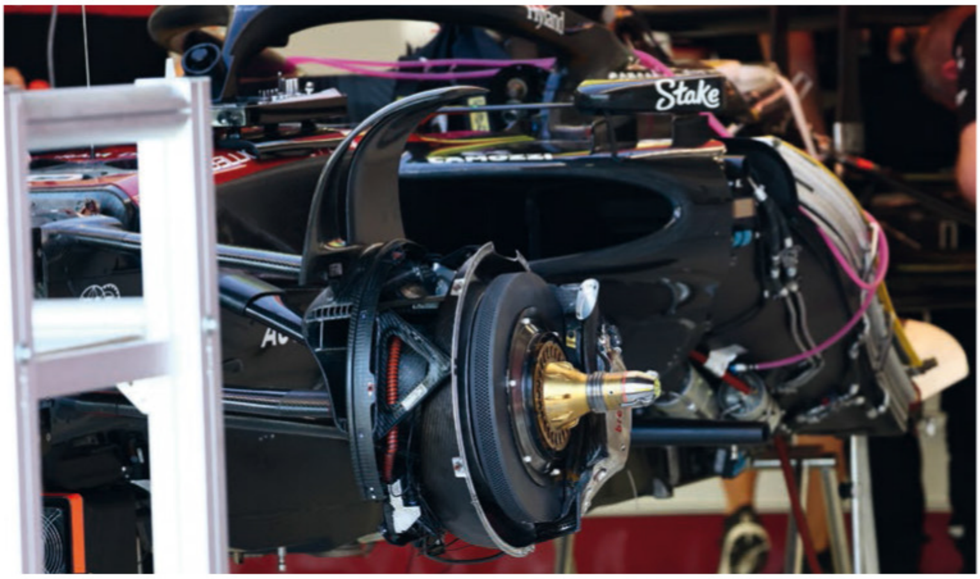
Aston Martin-Mercedes AMR23

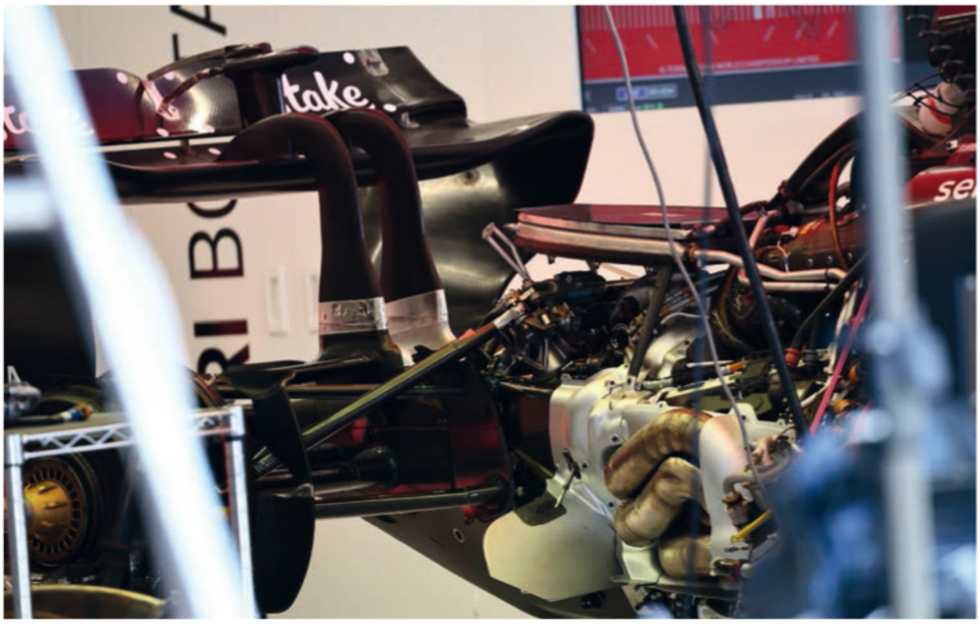
It's all change at Aston Martin, with Dan Fallows last year recruited from Red Bull as technical director, Luca Furbatto from Sauber as engineering director and Eric Blandin from Mercedes as chief aerodynamicist, while Andrew Green has been moved from F1 CTO to advanced projects.

Collectively, the team have engineered a car almost the equal of the Red Bull by drawing heavily on the pre-eminent design, down to the deeply sculptured sidepods and heavily inclined suspension wishbones, although in this case pull rods do the heaving, as opposed to push rods on the blue car.

In simplistic terms, the Aston Martin comprises a 2022 Red Bull front end mated to a complete Mercedes rear end, and it shows. In Bahrain, Fernando Alonso

In simplistic terms, the Aston Martin comprises a 2022 Red Bull front end mated to a complete Mercedes rear end, and it shows


The C43's sidepod and centreline cooling (above the PU, drawing air via the intake) has changed to increase sidepod ground effects


Although C43 uses a complete Ferrari back end, the rest of the car is closer in philosophy to RB19, so offers more predictable handling

Collectively, the team at Aston Martin have engineered a car almost the equal of the Red Bull by drawing heavily on that car's design

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ran rings around the W14 running the same powertrain while experiencing less tyre degradation. There must be a lesson in there for the Brackley folk.

'The car, it's relatively predictable,' explained Fallows after testing. 'It's kind of doing things we want it to do, so that is very positive for us. In terms of relative performance, it's really difficult to say. I'm delighted there's a lot of excitement around the team, but really, things are done so differently by different teams in testing that it's really this (race) weekend that we get some inclination of how good the car is.'

Two successive podiums for Alonso underscore the AMR23's qualities. Now the team has to learn to operate at the level of its double world champion driver, and the fullest potential of AMR23, so as to not squander the opportunity offered by having the current second fastest car on the grid.

Haas-Ferrari VF23

What to say about a team that sources all major hardware, including front and rear suspension, from Ferrari, uses the Maranello wind tunnel, has a design office situated within the bowels of the Scuderia and is managed by an Italian, save that the entire arrangement is totally legal, as outlined in 'Playing the game' (*RE* V32N12) and that similar issues to those experienced by the Scuderia can largely be expected here.

So it has proved, with both drivers qualifying strongly (via tyre warm up), but then dropping off the pace as degradation hits. The saving grace for the Haas team is that its struggles are not as public, but that is of little consolation for team owner, Gene Haas, when it comes to prize monies.

AlphaTauri-Honda AT4

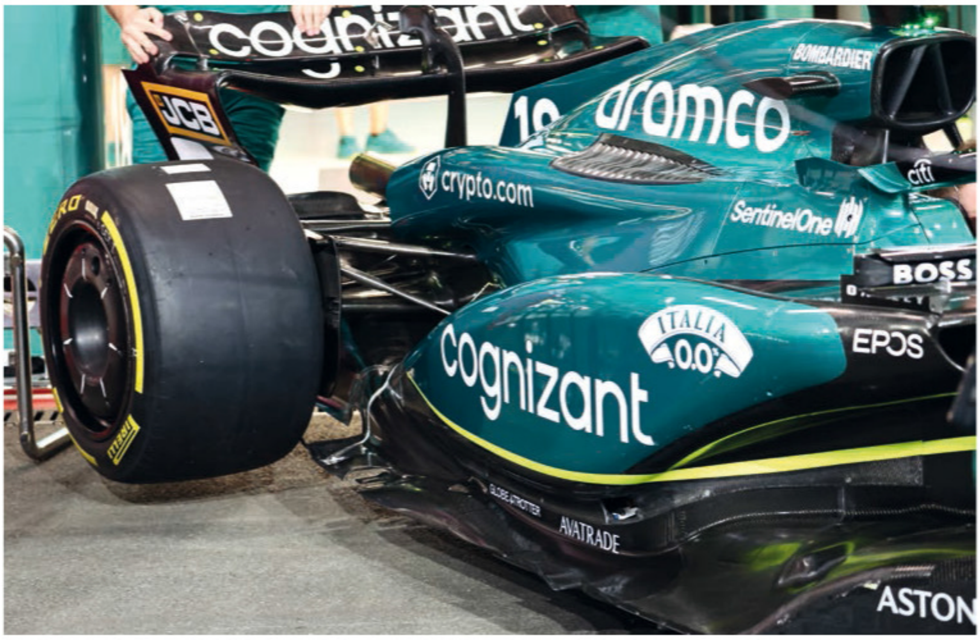
'Too little downforce, not enough downforce, therefore the car is unstable under braking, overheating the rear tyres, washing out at the apex, bad traction. Everything you need to do a good lap time [is missing].

'The engineers tell me we made some good progress, but I don't trust them anymore... I want to see it in the lap time because this is the only thing which counts.'

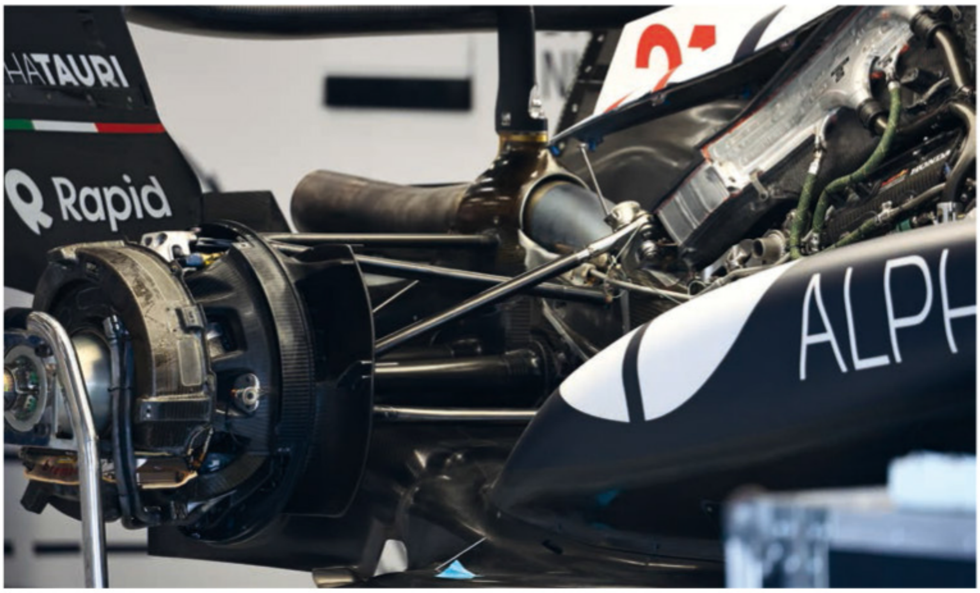
That is not our summary of the AT4, but a very public indictment of the situation from team principal, Franz Tost, in Saudi after both cars failed to make the points in Bahrain.

Bafflingly, AlphaTauri has access to sister, Red Bull's, wind tunnel, has its parts largely manufactured by Red Bull Technology and uses the identical rear end combination of Honda PU / Red Bull transmission, which dictates rear suspension mounting points and geometry.

'How can it be that we have the fastest car and the slowest?' Red Bull's F1 consultant, Helmut Marko, wondered aloud in Jeddah.



One notable difference is the AMR23 has pull rod rear suspension, as opposed to pushrods on the Red Bull that so clearly inspired it



AlphaTauri's AT4 uses the same rear end combination of Honda power unit / Red Bull gearbox as the RB19, which dictates suspension mounting points and geometry. It also has access to its sister team's wind tunnel and uses parts produced by Red Bull Technologies

So why then, according to AlphaTauri's team boss, does the AT4 not produce enough downforce, making it unstable under braking, overheating the rear tyres and lacking traction? It's a damning indictment of a car that shares a lot of learnings with the RB19

The Williams FW45 is largely an updated version of the previous year's car, with upgrades seemingly borrowed from across the grid

While the FW45 is extremely fast in a straight line, its distinct lack of downforce leaves its drivers lacking confidence in the corners

Williams-Mercedes FW45

Look at the Williams FW45 and it is the closest in design to the Mercedes, and little wonder. The two teams have long enjoyed a cosy relationship, with Wolff at one stage being a Williams shareholder and all but volunteering the services of ex-Mercedes strategy director, James Vowles, as team principal after Jost Capito stepped back in December, taking his long-time technical confidante, 'FX' Demaison, with him.

The team therefore has no official technical director, with FW45 being largely an updated version of what went before, with upgrades seemingly cribbed from across the grid. At least that was the summary of an opponent technical director who spoke frankly to *Racecar Engineering* on condition of anonymity.

What the team has is a searingly fast car in a straight line, combined with a distinct lack of downforce, which makes it a handful. The top speed – around 10km/h quicker than the next car – helped Alex Albon score a point in Bahrain by drafting past an AlphaTauri in the closing stages, but in Jeddah both drivers displayed a lack of confidence through the high-speed sweeps.

That, frankly, is the team's lot until a new technical director has their feet comfortably under the design board desk. Will Vowles grab a Mercedes engineer for the role? Don't bet against it.

Bar major reliability issues for Red Bull, there is no reason why the team should not walk both titles, taking the runner-up driver slot, too

Summary

Bar major reliability issues for Red Bull, there is no reason why the team should not walk both titles, taking the runner-up driver slot, too. For the rest, Aston Martin looks a shoo-in for best of the rest, ahead of either Ferrari or Mercedes, whoever sorts their issues soonest.

Behind them, a fight is expected to develop between Alpine, Sauber and McLaren, with Haas, AlphaTauri and Williams bringing up the rear.

But hey, less than the 10 per cent of the season is done, so the best that can be said at this stage is that not all F1 cars look the same.

IndyCar

Simulating environment

How 'America's Formula 1' has embraced simulation and developed into a world-class technology platform

By JAHEE CAMPBELL-BRENNAN

With an increased reliance on simulation, IndyCar is once again at the highest level of domestic and international motorsport

RLLR

IndyCar is sometimes referred to as America's Formula 1. It is fast, open-wheel, open-cockpit and high-downforce racing, driven by underbody aero and front and rear wings. It races with a familiar format, but is a very different championship, with an equally exciting journey.

In the late 1990s, the series raced under CART using Champ Cars. This was a relatively prosperous period for open-wheel racing in North America, with lots of sponsorship available and high viewing numbers.

Technological development in that period was fast, using cutting edge wind tunnels, shaker rigs and all the other R&D techniques you might expect from top-level racing.

Towards the end of the '90s, however, the Indy Racing League (IRL) broke off from CART and two separate racing championships were formed. Viewing numbers plummeted, presumably confused by what was going on, and with them went the sponsorship money.

At this point, the championship also moved from a multi-manufacturer series with many different chassis and engine builders, and relatively open regulations, to effectively a single-make series. This meant there was less reason to spend money on development, and innovation subsequently stagnated. In a short period of time, the series went from a position rivalling F1 to falling noticeably behind, with its reputation following.

In a short period of time, the series went from a position rivalling F1 to falling noticeably behind, with its reputation following

In recent times, though, IndyCar has re-surfaced and is once again being held up as one of America's premier racing series, with a very healthy fan base, lots of commercial investment opportunity and strong manufacturer involvement.

With a major regulation change coming in next year through the introduction of a hybrid powertrain, the sport is about to undergo perhaps its greatest technological revolution yet. This presents a perfect opportunity to explore its journey over the last decades and see how IndyCar finds its place within top tier international motorsport.

Simulation revolution

Let's begin by understanding the influence regulations have in directing technology in motorsport. In today's championships, any discussions on the subject are largely focused on simulation, and how it benefits the engineering process from a cost, timing and quality standpoint.

Simulation technology has been used widely in global championships as an addition to physical testing for many years and, when the IRL was established in the late 1990s, teams were already using some basic simulations for off-track car development. These consisted of rudimentary MATLAB and C code-based lap time simulations, damper dynamics models and computational fluid dynamics (CFD).

While simulations back then were used differently from how they are today, the fundamentals remain effectively the same. The objective is to enable engineers to understand the performance sensitivities of the car on any particular track, and to direct engineering efforts accordingly. It also allows the study of questions, such as: Is the powertrain, aero or mechanical set-up the most important to focus on in order to find performance and lap time improvements?

Over the years, IndyCar has dramatically reduced opportunities for physical testing during the racing season. This is noteworthy as it marked a turning point at which simulation transitioned from a complement to track-based development to an alternative. This switch in mindset dominates the focus of innovation within motorsport.

In 2004, there were 16 races in IndyCar and the opportunity to perform 17 test days. Now, there are only two days of track testing allowed per season, but with an equal motivation to develop the cars and gain advantage over the competition.

'The change in regulations gave rise to a lot of adaptation in IndyCar and the push to use simulators in a heavy way. We had to find a way to still develop the car, and this changed the landscape of our technology quite a lot,' comments Ricardo Nault, team manager at RLL Racing.

Opportunities for physical testing are few and far between for IndyCar teams today, so they're having to investigate other avenues

Simulation in today's IndyCar predominantly means the use of computing power to perform CFD and vehicle dynamics studies. Since IndyCar only began using this technology in anger relatively recently, technology transfer is particularly prominent.

With so much reliance on digital innovation, it's logical to look to those who are leading the field for inspiration as to how best to use it. Inevitably, this expertise comes from Formula 1, and teams like RLL Racing have appointed some very experienced leaders within their organisations.

Stefano Sordo, for example, moved over to IndyCar from McLaren Racing's F1 team, where he brings his experience as director of vehicle performance, and two decades of racing in F1, to serve as RLL's technical director. He is well acquainted with the directions simulation technology can take the sport, and the methodology required to maximise its use.

Incremental gains

However, where once there were relatively large gains to be had simply from running a basic simulation, with more time spent developing the cars to an ever-tighter set of regulations, the increments of performance gain have become increasingly smaller for a given engineering effort.

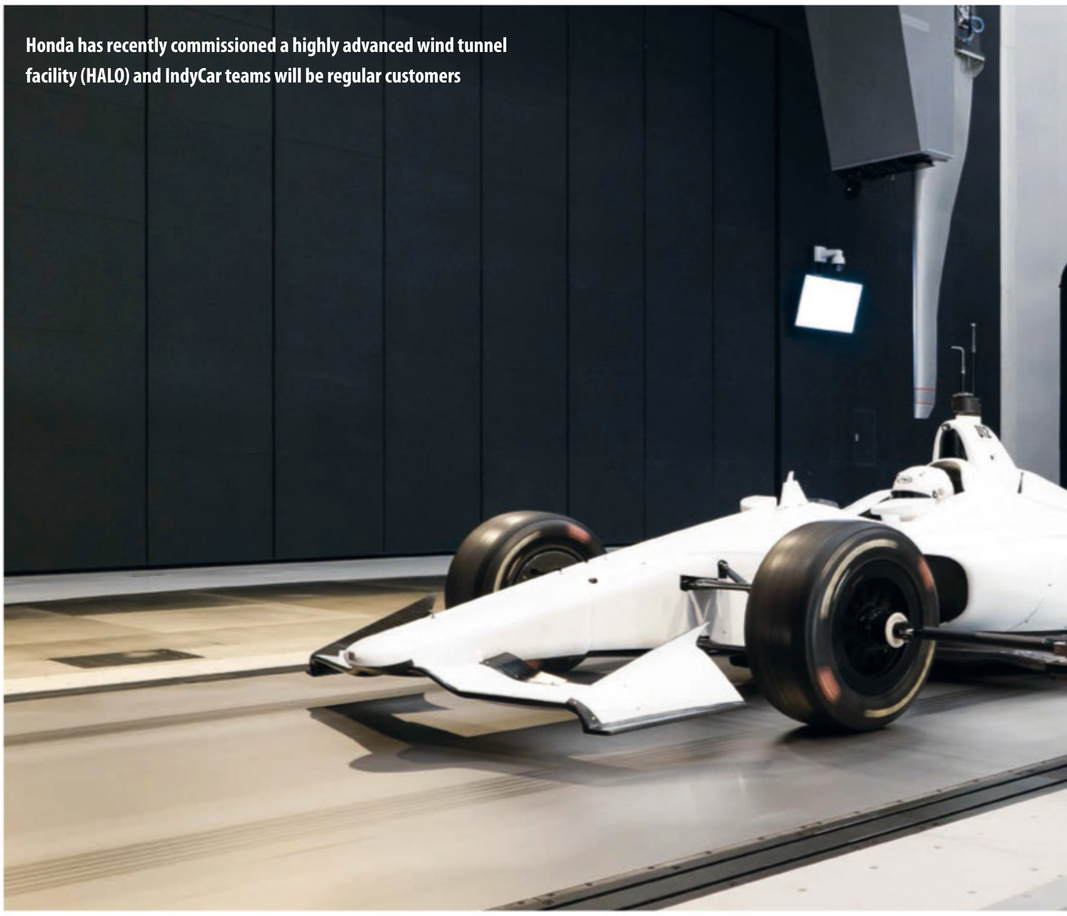
Today, the atmosphere is such that the fidelity of physical understanding required to make meaningful advancements is placing new demands on both the technology and our understanding of the physics behind it.

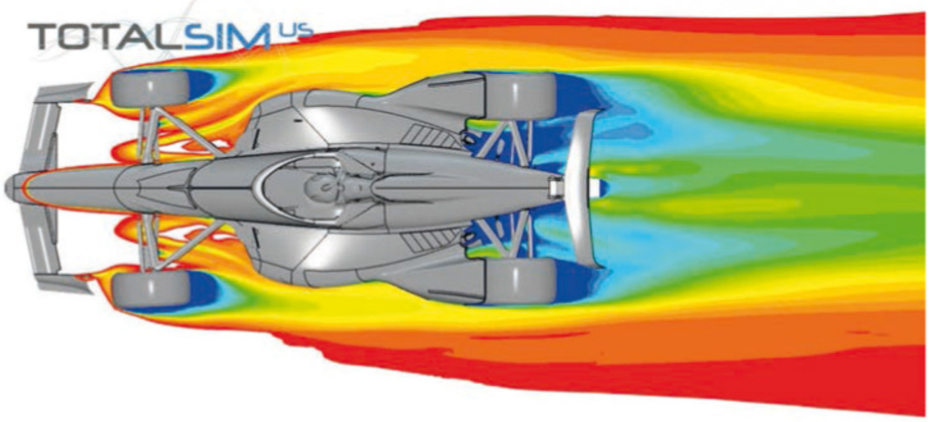
'Understanding the car aerodynamically was my first task when I arrived here,' recalls Sordo. 'We needed to understand how to efficiently manipulate the mechanical set-up of the car to maximise our aerodynamic performance through thorough physical measurement, CFD and wind tunnel work.

'Once we have the data from this testing, part of the exercise is wind tunnel and CFD correlation, so we can understand how this data matches data from the track and can use them as reliable tools.'

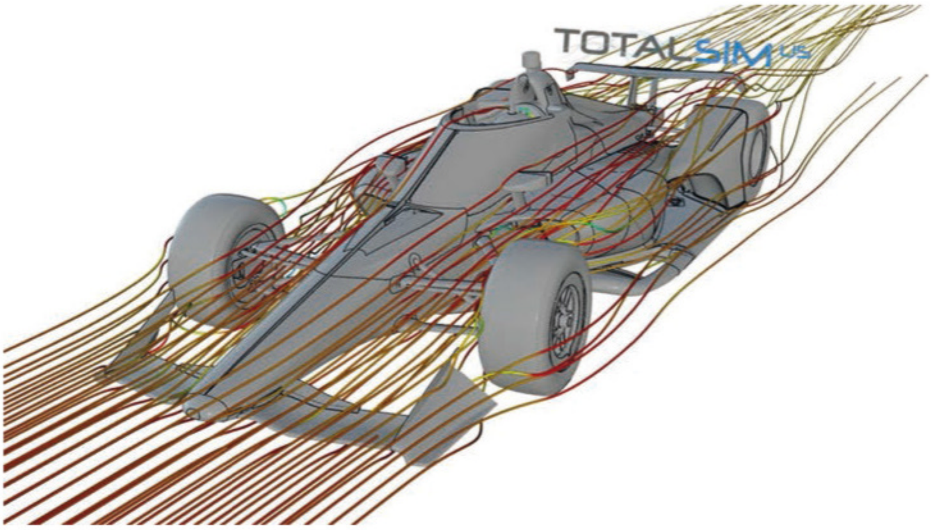
Logical process dictates that the task of the highest importance in any performance development process is to understand what is happening to the car in the real world first and foremost. Any off-track development efforts must ultimately support that.

'In 2009, when we started doing CFD for Indy at TotalSIM, it was about getting information that we couldn't get elsewhere,' notes Ray Leto, former technical director and president of TotalSIM, who supplies teams in the championship with aerodynamics expertise. 'It was adding to the wind tunnel activities and, while we weren't trying to correlate strongly between them at that time, we were trying to better understand flow structures around the car.


Honda has recently commissioned a highly advanced wind tunnel facility (HALO) and IndyCar teams will be regular customers



CFD has helped teams develop a greater understanding of flow structures work around the car



TotalSIM

Honda Newsroom

'The wind tunnel gave us numbers but didn't really allow us to understand what was going on, which is where CFD came in.'

Confidence in correlation

Typically, the wind tunnel enables engineers to understand the forces and moments generated around a vehicle in a reliable and representative way by measuring lift and drag performance numbers. It doesn't say a great deal about the flow structures around the vehicle, though, which makes correlation between track and tunnel a more difficult task. This is one of the merits of CFD, which simulates the flow field around the body.

'The simulations only give you as much confidence as the data you feed them with, so this goes back to needing a better, higher fidelity understanding of the car to feed into the simulation,' adds Sordo.

'It was pretty clear immediately that there was not enough instrumentation to understand the car on the physical track, so we have some tests in which we are going to make use of a full suite of aero instrumentation.'

The value in measuring pressure around the body with pressure tapping as it runs in the real world and in the wind tunnel is that it allows engineers to create a map of air pressure around the vehicle. This gives insight into areas of good flow attachment and separation, as well as vortices and other flow phenomena.

Crucially, it also records the magnitudes of the high and low-pressure zones around the wings, underbody and vehicle body. If the pressure coefficients look identical between the real data, wind tunnel data and CFD data, the mission is a success.

As you might imagine, though, this is rarely the case in real life.

'One of the things I'm doing here is to start using CFD methodologies as a tool to understand the car with a consistent and methodical approach. We are really aiming just to advance our understanding from trackside, not only to know what is happening on the real car at the track, but also to understand where our wind tunnel and CFD data are accurate, and where the are not,' explains Sordo.

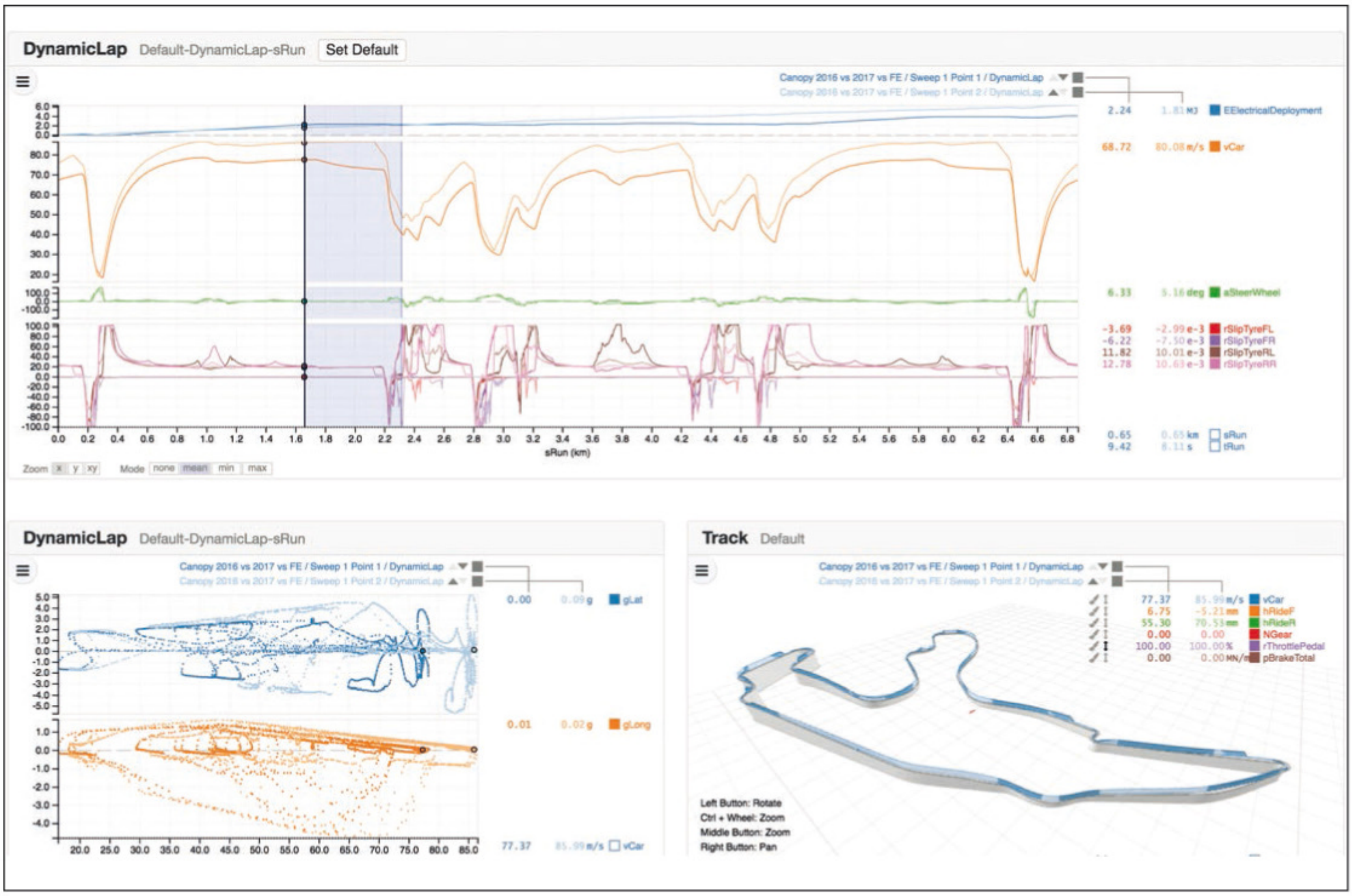
Restricted space

IndyCar is a spec series, which means that all teams have to work with the same aero kit, but there are still advantages to be found within this restricted engineering space, so a sound aerodynamic understanding is no less valuable.

With more time spent developing the cars to an ever-tighter set of regulations, the increments of performance gain have become increasingly smaller for a given engineering effort

HPD

Increasingly sophisticated vehicle dynamics models allow simulation to correlate more closely with wind tunnel data and information gleaned from on-track running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Ctrl + Wheel: Zoom
Middle Button: Zoom
Right Button: Pan

Canopy Simulations

Offline simulations allow large numbers of set-up variations to be analysed in detail, giving great insight into performance within a certain environment

'We are somewhat limited to influencing mechanical set-up through understanding where we want to place the car within the aero map for a given event,' continues Sordo. 'There are many things that can be done on speedways, and to a lesser extent road courses. We have minimum and maximum tolerances around the nominal surfaces we are permitted to be within, so there is still scope to understand good and bad directions.'

'At places like Indianapolis, for example, where you are power limited, small aero changes make a huge difference,' confirms Leto. 'At those speeds, five counts of *CdA* are worth 0.5mph, which is a lot of positions on the grid. Those increments are difficult to measure, even in a controlled environment like the wind tunnel.

'You can get repeatability and confidence windows, which allow you to make choices at that level, but it is not a trivial exercise. The instrumentation and preparations required are extensive, but this is the level of fidelity we work at in IndyCar today.'

Alas, aerodynamics is only one part of the IndyCar technological revolution. The aerodynamic platform must also interact with the vehicle chassis, and this segues nicely into the subject of vehicle dynamics.

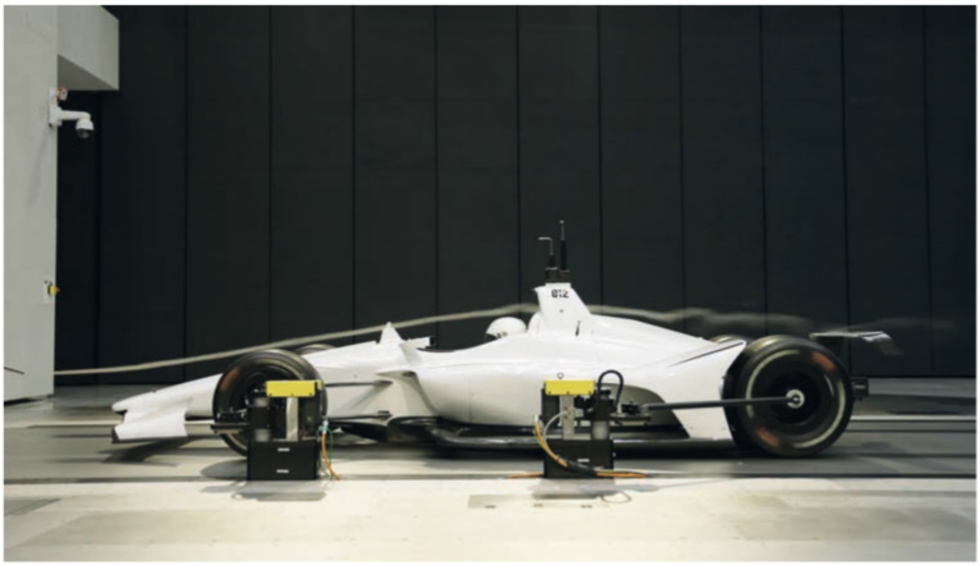
Simulation in this area in IndyCar has been making its own leaps and bounds, perhaps even more so than aerodynamics.

An integral part of performance development is vehicle dynamics simulations. This began as simple 'offline' simulations, a term used today to describe lap time simulation done on office-based machines.

Dynamic simulation

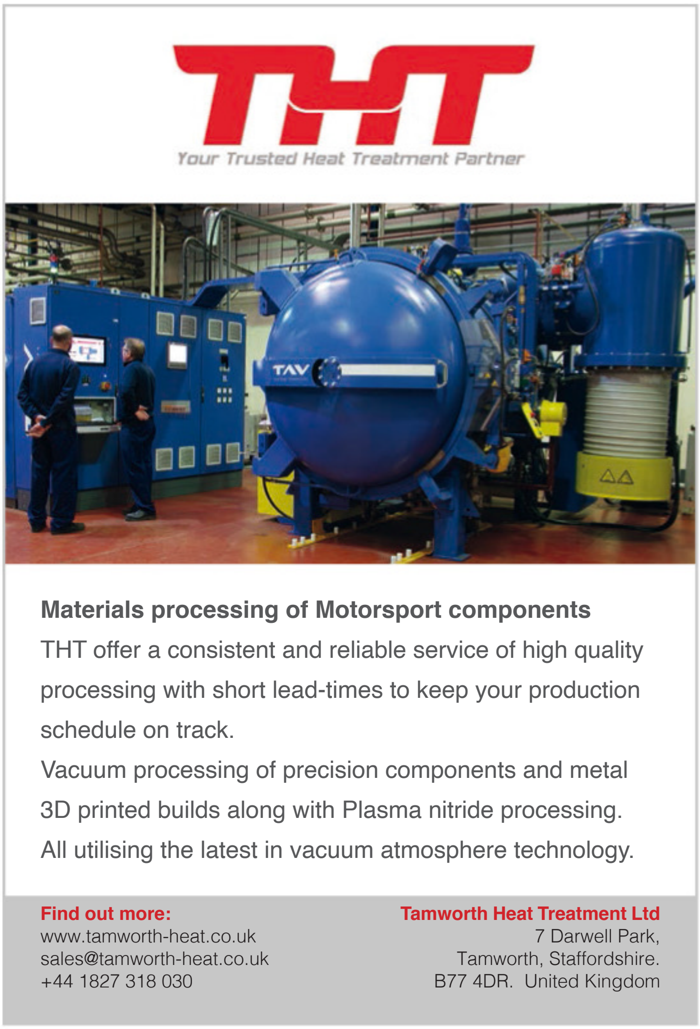
The key benefit of offline models is simple: they allow engineers to run through many different iterations of vehicle configurations with much faster turnaround and lower cost than you ever could with track testing. Running through 1000 different set-ups may take one evening of computing time, but you can imagine how long that would take on track. To perform any vehicle dynamics simulation, the first task is to create a digital twin of the car, which requires a very good understanding of the physical vehicle.

With certain characteristics such as kinematics, wheelbase and weights, this is a straightforward task, but moving into the realm of damper models, chassis compliances, tyre models and creating



Honda Newsroom

The aerodynamic development trio in today's IndyCar includes track testing, CFD analysis and wind tunnel testing. Correlation is key



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accurate representations of other non-linear parameters, the difficulty is another level up.

'We are doing some testing on the K&C rig soon to understand how the compliances of the car are distributed,' notes Sordo. 'Tyre testing is particularly tricky, because IndyCar forbids a slip angle sensor on the car, which means we are limited in what we can understand from the tyres.

'The tyre model is the most challenging aspect of this development.'

All IndyCar teams are given a tyre model by Firestone based on the Pacejka formula, but that digital representation omits many salient, physically-based parameters such as the effect of temperature and degradation on their attributes. Consequently, teams are looking to develop their own models, or adapt the standard model, to give an improved representation of the tyre.

'The methodology is to understand the car on track and then develop digital models that are a better representation of the car to feed the simulator in a more realistic way,' Sordo confirms.

The wide variety of IndyCar circuit types presents some unique engineering challenges. Covering ovals, speedways, road courses and street circuits means setting the car up well for tracks ranging from bumpy public roads with coarse concrete to finely laid asphalt on banked ovals and open, sweeping, European-style circuits. The requirements of each track dictate an entirely different chassis and set-up approach.

Optimising performance over different wing packages, ride heights, damper rates, spring rates and kinematics therefore presents a hugely complex engineering challenge for teams, so the vehicle models need to be robust for engineers to have confidence in the simulation data and follow a certain set-up direction at each race weekend.

The software used to perform offline simulations is not proprietary to individual teams, as in some other series, which means the creators of such software can reference the fidelity of vehicle models in IndyCar relative to a spectrum of other championships.

'I can tell you, based on the features we've been asked to build, that IndyCar modelling is as rigorous as you'll find anywhere'

Jon Mullen, software developer at Canopy Simulations

'There's plenty of times IndyCar has pushed us to develop new technology that's ultimately been used elsewhere,' notes Jon Mullen, software developer at Canopy Simulations. 'One of the great things about working in as many series as we do is getting to see technical innovations and regulations be adopted and adapted by different series.

'I can tell you, based on the features we've been asked to build, that IndyCar modelling is as rigorous as you'll find anywhere.'

Chassis platform

The chassis platform of the IndyCar is largely conventional, using inboard springs and dampers with de-coupled heave springs in a conventional way, but IndyCar does allow the use of inerters, which are prohibited in all other high-level racing series.

Inerters have the effect of attenuating vibrations experienced by the unsprung mass introduced by inputs from the road surface. The result is a reduction in contact patch pressure variation and an increase in average grip vs traditional systems. They have a significant impact on the cars' behaviour, so accurately capturing their effect is important.

IndyCar also permits the use of a component called the weight jacker. Fitted to the right rear spring, it allows drivers and engineers to shift weight around the contact patches by lengthening or shortening that corner's spring/damper unit to alter the corner ride height, and therefore centre of mass positioning. It also has the secondary effect of placing the car in a different position of its aero map to influence the centre of pressure and drag.

This is another important interaction, which can only be captured effectively with sophisticated and accurate vehicle models.

'The funny thing about the weight jacker is that it was more difficult to make realistic in practice than it was to model its physics,' says Mullen. 'Our optimisation wants to adjust it mid-corner – which is a little much to ask of a driver – but we managed to make it realistic and useful to teams.

'Teams tend to focus effort on modelling the components they think their car is most sensitive to, and then exploit places where they're given freedom by the regulations.

'IndyCar is a unique sport, so we see technical innovation focussed in unique ways.'

These interactions between complex suspension systems can cause real challenges without a solid methodology and database to approach simulation with.

'We've been doing this long enough to understand how to drive engineering in that sense,' says Nault, 'but the developments in simulation technology have for sure helped us to be more organised, and to understand how what we learn at one style of track will transfer over to another.

DiL simulators used by IndyCar teams represent all the important inputs to allow drivers to interact with the vehicle dynamics software

'Because the wing package and damper requirements are so different, it's largely a different car from one track to the next, and the set-up approach is so different, but simulations have helped massively.

'The databases we now have make it easier for engineers to focus on things that will help effect change to make the cars faster.'

Driver input

Offline simulations have undoubtedly allowed teams in IndyCar to make large steps forward to understand their cars better, and have provided part of the solution to the lack of physical track testing opportunities in the championship. But there is a second, logical evolution to vehicle dynamics simulation, which is emerging as an even more powerful tool.

Driver in Loop (DiL) simulators follow on from offline simulations to provide a physical

RLLR

‘The databases we now have make it easier for the engineers to focus on things that will help effect change to make the cars faster’

Ricardo Nault, team manager at RLL Racing

environment for the driver to interact with the digital vehicle model through standard controls – steering wheel and pedals. This immediately overcomes several limitations of the offline simulation.

Firstly, it’s not straightforward to obtain meaningful data on subjective parameters, such as the driver’s experience of vehicle stability, from offline simulations. Offline simulations also assume the driver will take the mathematically optimal trajectory around a circuit, when in reality features such as bumps, cambers and curves can make this a slower way around. There’s also no accommodation for traffic, and how that alters the driver’s inputs.

The engineering process is to use offline simulations to narrow down a window of possible set-ups, and then send those over to the DiL, where the driver can be involved in deciding the set-up direction they are most comfortable with. It’s the output from the DiL, which is then run through at the track in practice sessions to arrive at optimal qualifying and race set-ups.

That said, simulator time is also limited in IndyCar, and teams are restricted to 12 days per season, compared to Formula 1 where teams can be in the simulator three or four days a week, all year round. Care must therefore be taken to make the best use of the available time, especially as teams currently do not have in-house rigs, instead relying on those at series suppliers such as Honda and Chevrolet.

With effective execution of vehicle dynamics simulation, the race weekend becomes an easier process.

‘With better management of resources, it’s probably fair to say we have reduced the complexity of a race weekend. Through the progress we have made in simulation, it becomes an easier task to evolve the set-up over a weekend,’ confirms Sordo

Exciting opportunity

To maximise the benefit of using these technologies, teams also need to be re-structured to put the right personnel in the right places, which means bringing in experienced engineering resource in the important new development areas such as tyres, aero and CFD methodology, something RLL Racing identifies as an exciting opportunity for engineers.

‘In contrast to F1, where you can be a tiny cog in a huge wheel, you can effect more change in IndyCar,’ says Nault. ‘The real racers are interested in having a larger part in the car’s development. Our team, for example, which is split across IndyCar and IMSA, is running five cars full time with only around 120 people, so we are still relatively small.’

So, where is IndyCar headed? It's certainly an exciting time to be in the sport as it develops and adapts to current technologies. And while this is a journey rather than a destination, the continued emergence and development of technologies can provide insight into what the sport may look like in the next five years.

The introduction of hybrid powertrains will undoubtedly be another turning point in the series, and while regulations on its integration into the racing are yet to be crystalised and communicated, information is starting to trickle down to teams, and thoughts on how best to use it are already progressing.

'Next year, our IndyCar team will be running KERS, so it's going to be very interesting to learn and to understand how to deploy the assistance and regen,' says Nault. 'We aren't entirely sure what level of engineering support the regulations will allow, but it seems like we won't be allowed to programme the deployment and regen' and that it'll rely solely on the drivers.'

> **'Through the progress we have made in simulation, it becomes an easier task to evolve the set-up over a [race] weekend'**
>
> *Stefano Sordo, technical director at RLL Racing*

Again, this is in contrast to Formula 1, Formula E and the World Endurance Championship, which all feature programmable deployment and regen' strategies to suit the track, driver and phase of the race. Giving the driver more opportunity to get it wrong, or right, is almost certain to produce some great racing.

Machine learning

Artificial intelligence and, more specifically, machine learning is another rapidly developing technology across all industries these days, and motorsport is no different.

The vast array of sensor data recorded by these cars over a race weekend is useless unless it can be utilised to drive decisions within the team. Analysing data is a time-consuming task and, not only that, you have to know what you're looking for.

Machine learning techniques have the potential to allow vast amounts of data to be processed, and trends and patterns identified, in order to generate meaningful conclusions in an efficient way. The technology is in its infancy in IndyCar, but in F1, where RLL's technical director has professional experience, it's more developed.

'In F1, AI has become increasingly important in various areas, but mainly in aerodynamic testing where, for example, it can reduce the post-processing time of CFD results,' explains Sordo. 'We'll use this technique to further our understanding of the car, but it's more of a long-term plan. An area I think AI can also be useful in is linking sector time data to performance sensitivity of the car based on what we have learnt in testing. This is a clear path forward I think.'

Given that IndyCar circuits have lots of sectors, up to 10 in some, this provides good references to identify correlations between the circuit features within each sector and aerodynamic configurations.

While the computing power available for simulations is increasing exponentially, new opportunities and complexities within simulation can be realised. Capability with CFD is especially interesting in this respect, particularly in what is possible for the simulation of airflow across multiple cars running in close proximity.

'We've been doing more and more traffic studies and multi-car simulations of late,' says Leto. 'There are a lot of ways to do that, but we've developed quite a nice process in IndyCar and NASCAR.

'In traffic at speedways, for example, the interactions between the cars at those high speeds are more important than the individual car aerodynamics, and drafting is so important, so being able to look at a free air car and a car in traffic is key.'

These developments in capabilities also allow studies to be done on the aerodynamic interactions between the car and the wall when it's running close to it - another feature that sets IndyCar apart from other open-wheel series. Not only do these allow an aerodynamic understanding of the flow in these conditions but, along with the data gained from traffic simulations, this can be fed into the DiL to give drivers a much more realistic vehicle model.

It's a safe bet to say IndyCar will have progressed a long way in the coming years, and the gap between it and its racing cousins in F1 will continue to decrease.

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IndyCar

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3D
15
CATIA
RACING

There is room for only one car in the Winner's Circle and every motorsport race team has that singular ambition. However, the road to the finish line is filled with obstacles, including strict time and budget restrictions, stringent technical regulations, and the need to make split-second decisions – seemingly 'on the fly'.

The Multiphysics Simulation Toolbox

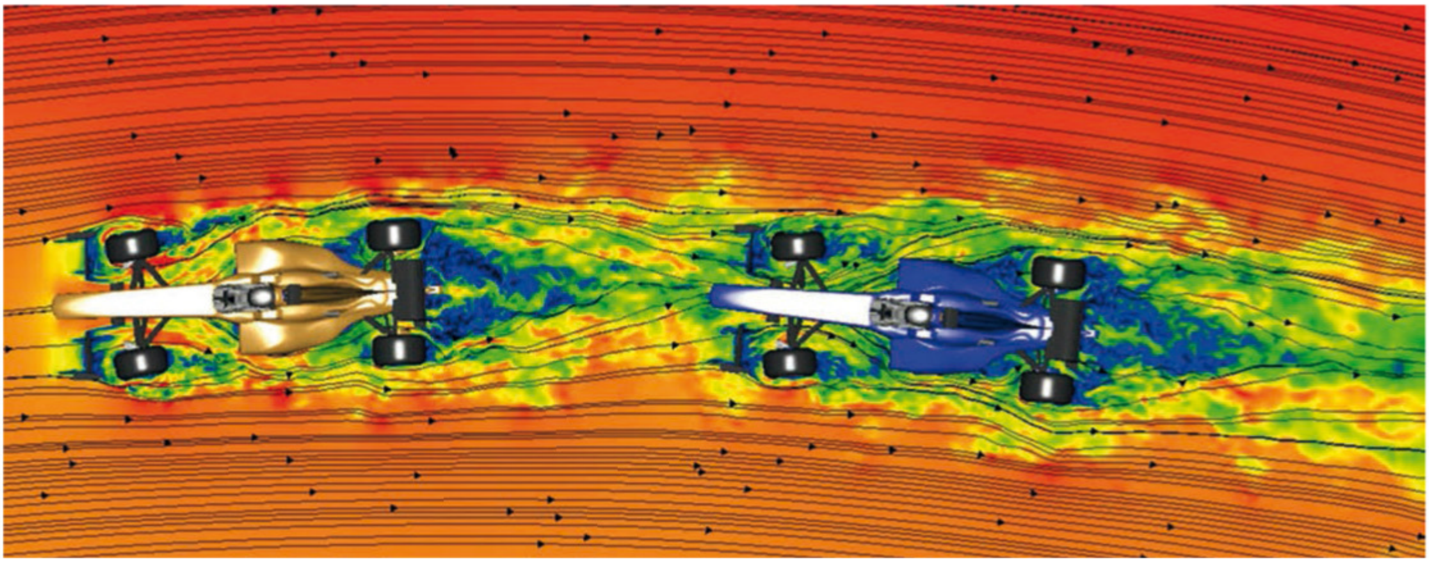
To overcome racecar development challenges, teams have embraced the use of computer-aided design (CAD) and computer-aided engineering (CAE) software for decades. Today, most race teams use a wide range of simulation codes to reach the best vehicle performance. Through its SIMULIA brand, Dassault Systèmes develops and delivers a broad range of multidiscipline, multiphysics simulation applications that are used extensively in automotive, aerospace, and the motorsports industries.

Race teams across all platforms, face limited time and budget for wind tunnel testing. This makes it critical for teams to leverage computational fluid dynamics (CFD) for aerodynamic analysis. Advanced CFD simulation capabilities such as those provided by SIMULIA PowerFLOW enable engineers to analyze the turbulent airflow around a vehicle and optimize its aerodynamic design. SIMULIA XFlow is used to simulate engine lubrication and fuel tank sloshing effects. The use of robust and proven CFD applications reduces the need for physical testing and helps teams make design improvements that help improve vehicle handling, and fuel efficiency.

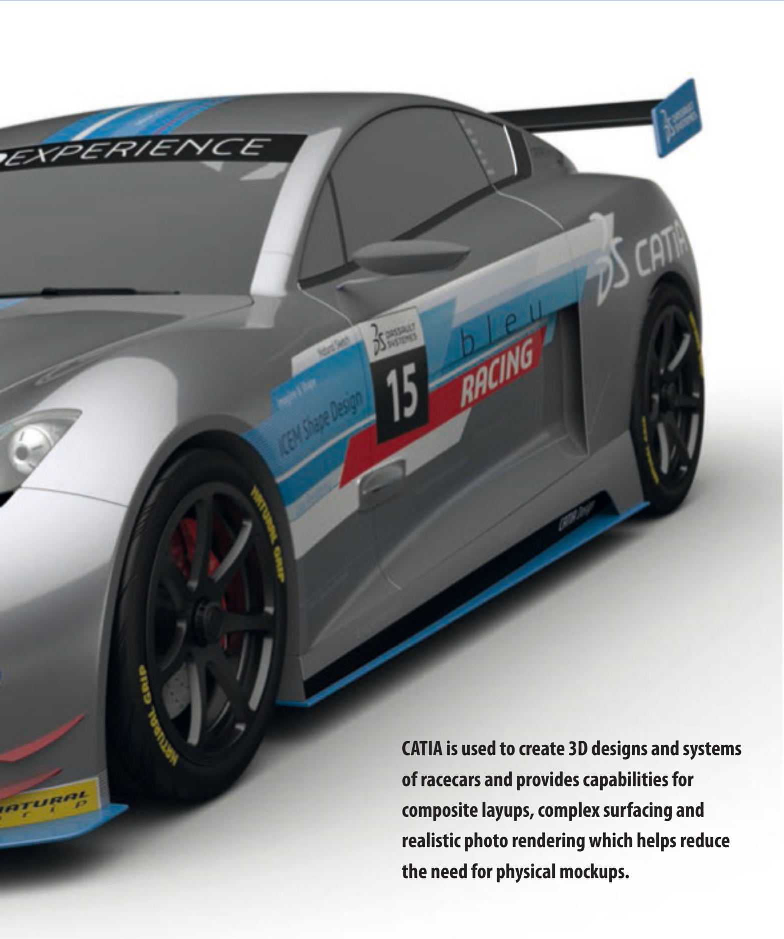
Another key simulation technology is finite element analysis (FEA), which is used to evaluate the structural integrity of the body, chassis and critical components. SIMULIA Abaqus provides linear and nonlinear structural analysis capabilities. This technology makes it possible to analyze the behavior of a wide range of materials used within a racecar, including composites, metals, plastic and rubber. Combining Abaqus FEA with SIMULIA's design optimization applications enables engineers to optimize the structural design for maximum strength and stiffness while minimizing weight.

Abaqus is also used to perform thermal-mechanical analysis ranging from thermal expansion in engines to friction-driven heat transfer such as in brake systems to fully coupled temperature-displacement simulation, in which motion affects heat transfer. PowerFLOW enables engineers to analyze airflow cooling for engines, brakes and cockpits to evaluate and improve designs to prevent overheating and improve reliability.

SIMULIA Simpack multibody simulation (MBS) is used to analyze the dynamic motion of mechanical systems including engine pistons, drivetrains and gears, clutches, suspensions and vehicle dynamics. Simpack



Aerodynamic simulation of racing F1 cars in a cornering maneuver with SIMULIA PowerFLOW.



CATIA is used to create 3D designs and systems of racecars and provides capabilities for composite layups, complex surfacing and realistic photo rendering which helps reduce the need for physical mockups.

SIMULIA Simpack driving simulator enables product development teams to experience real-time vehicle performance in a wide range of operating conditions, with software-, hardware- and driver-in-the-loop capabilities

enables the creation of full 3D components within the system to evaluate realistic forces of components interacting within the full mechanical system. In the case of vehicle dynamics, engineers are able to analyze and optimize vehicle design for maximum handling and stability.

Simpack provides unique real-time, man-in-the-loop driving simulator capabilities, which enables race teams to put their drivers into the seat of a virtual racecar. This allows them to analyze software-, hardware- and man-in-the loop scenarios to get realistic, real-time feedback from the driver's perspective of the handling and suspension under various track conditions, including cornering, to rapidly influence design decisions.

Teams are also able to use MBS for offline lap time simulations and perform design tradeoff studies, such as evaluating how changes to vehicle styling, suspensions, or engine modifications influence lap time performance.

Digital Transformation with a Cloud-based Platform

However, even within the close confines of a race team, these simulation tools are often being used by silo'd specialists and the results do not always keep pace with design iterations. The never-ending quest for cost-control, incremental performance improvements, and speed has created the need for digital transformation within the motorsports industry.

Key to achieving the promises of digital transformation is a shared, digital cloud-based platform that facilitates on-site and remote work arrangements and lowers IT hardware and maintenance overhead. A cloud-based platform such as the **3D**EXPERIENCE platform from Dassault Systèmes allows teams to share functional requirements, collaborate on conceptual and detailed designs, and perform realistic simulations of components and systems - including aerodynamics, powertrains, body, chassis, suspension, tires, braking, and safety.

The **3D**EXPERIENCE platform allows development teams to free their design and project data from personal email inboxes and file folders by enabling them to share models, simulations and status updates through planners, apps and online communities.

Unified Modeling & Simulation (MODSIM) on the **3D**EXPERIENCE platform enables designers and simulation specialists to collaborate on the same design model thus avoiding translation and version control issues between CAD and CAE.

Design associativity along with rules-based and automatic meshing capabilities enable race teams to shave hours and even days off the traditionally manual process of updating simulation models and meshes with every design change. Time reduction of a factor of 10 has been reported for select unified design and simulation workflows when compared to traditional silo'd processes and tools.

For example, they are able to use CATIA with the SIMULIA Fluid Dynamics Engineer role to analyze pressure in fuel lines or exhaust systems or create lighter components with SIMLUIA optimization technology embedded in the CATIA Structural Generative Design role. The platform enables them to share the design and simulation results with stakeholders immediately for their review and comments, no matter where they are.

The platform provides guided simulation workflows, which allows designers to use approved methods to rule out potentially unworkable designs before final design work has been done, which reduces re-work of design models based on disparate simulation results.

Process automation and optimization technology combined with design and simulation apps on the platform enables design and engineering teams to use parametric anon-parametric methods to explore hundreds of design alternatives to accelerate collaborative, performance-based decisions.

The **3D**EXPERIENCE cloud-based platform provides race teams with access to the right technology whenever and wherever they need it. This includes 3D Design, functional generative design, systems modeling, structural analysis, electromagnetics simulation, fluid dynamics, multibody simulation, process automation, as well as apps to manage functional requirements, decision support, and manufacturing processes.

The platform enables teams to manage and share a single source of design and simulation information that is secure and easily accessible by all team members regardless of location or time zone. This allows them to create more design alternatives and simulate realistic vehicle performance more efficiently and with more confidence. This digital transformation of their development processes results in faster turnarounds and lower costs, which supports their ultimate goal of being 'the only one' in the winner's circle.

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Forze of nature

Racecar investigates Delft University of Technology's pioneering hydrogen fuel cell racer

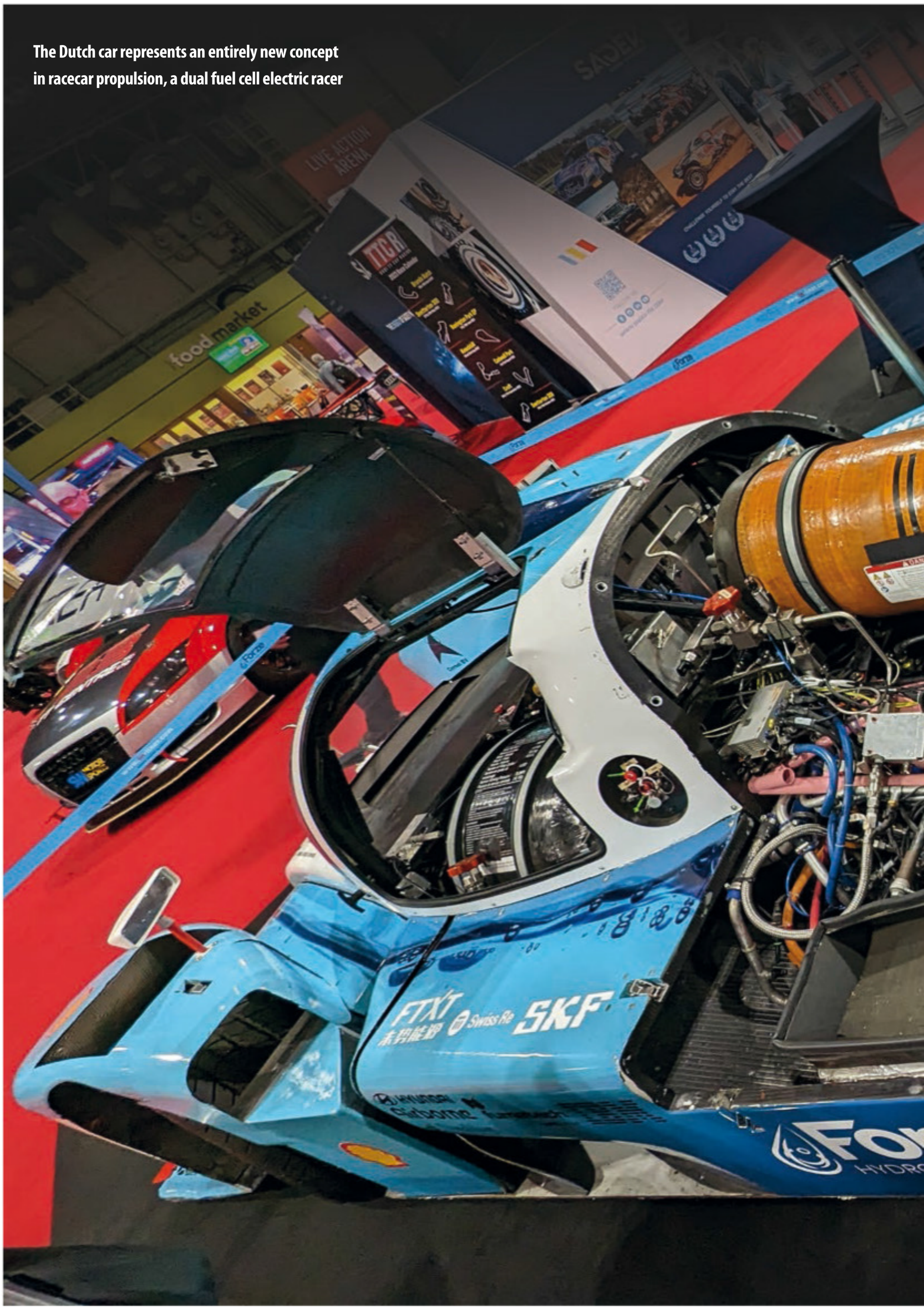
By STEWART MITCHELL

Hydrogen is an abundant element when it comes to fuelling propulsion. Its potential to replace liquid fuels in internal combustion engines is an exciting prospect for many car makers, and the drivers for its implementation in that regime are vast. However, there is another significant opportunity for hydrogen in vehicle propulsion in the form of hydrogen fuel cell electric power.

A team of TU Delft technical department students and several engineers external to the university have designed, built, and raced a hydrogen fuel cell electric-powered prototype to demonstrate the possibilities for hydrogen in motorsports, mobility and more.

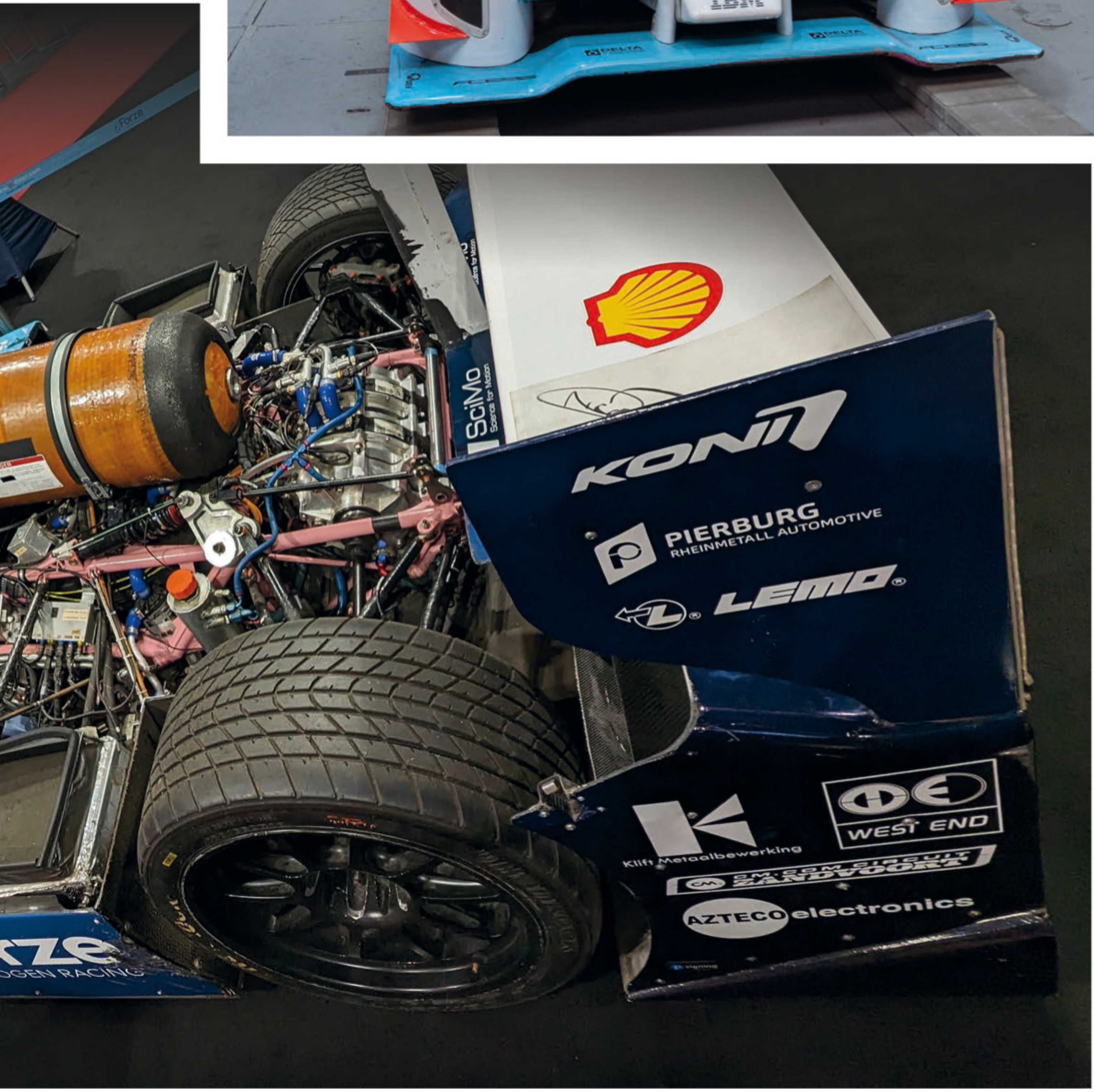
The team, called Forze Hydrogen Racing, was set up to accelerate the marketing, activation and visibility of hydrogen and the technology inside fuel cell cars. The result is a collaboration of academic programmes and industrial partner-engineered design, providing a laboratory environment to develop hydrogen fuel cell technology under rigorous racing conditions.

The team was set up to accelerate the marketing, activation and visibility of hydrogen and the technology inside fuel cell cars



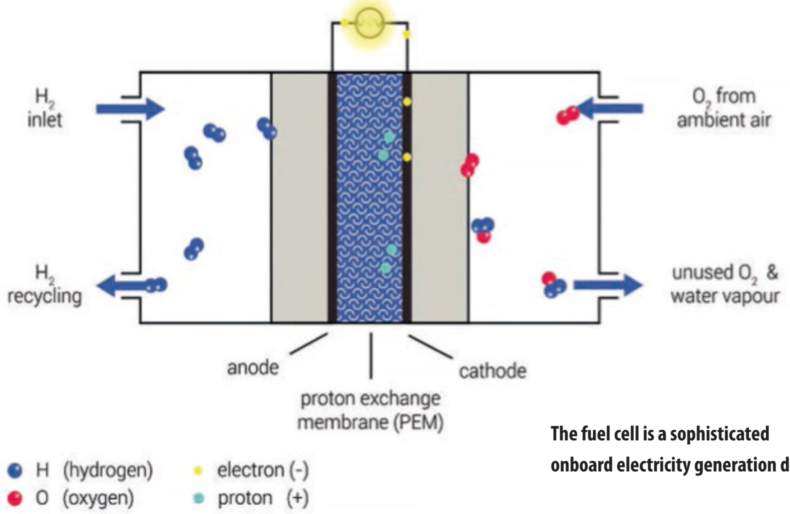
The Dutch car represents an entirely new concept in racecar propulsion, a dual fuel cell electric racer

Based on a prototype chassis, the amount of technology onboard meant packaging of the powertrain and cooling systems were major challenges for the team

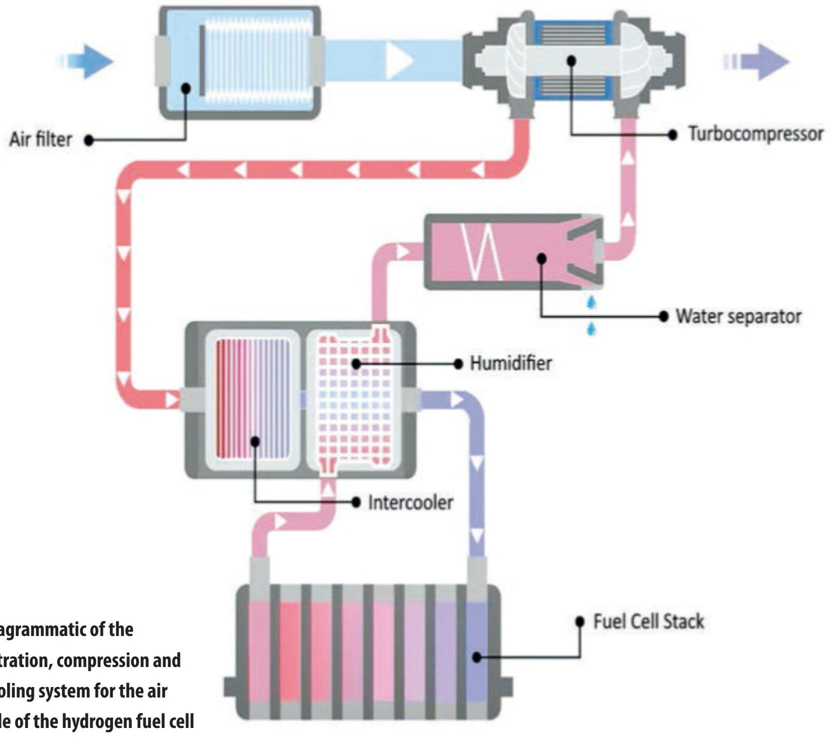


All images courtesy of Forze Hydrogen Racing Team

Forze Hydrogen Racing was founded in 2007 and started by putting small fuel cells on a go-kart. The latest car, the Forze IX, is a full-scale prototype racer that currently competes in an Open GT racing class in The Netherlands. It is considered a breakthrough in hydrogen fuel cell electric car performance.



The fuel cell is a sophisticated onboard electricity generation device



Diagrammatic of the filtration, compression and cooling system for the air side of the hydrogen fuel cell

Fuel cell operation

The Forze IX is an electric-powered prototype racecar with a supercapacitor accumulator, and two independent EKPO fuel cell stacks that produce its electricity. The sensitive operation of the hydrogen fuel cell makes designing one for the racecar application challenging.

The oxygen required comes from the outside air, which is scooped in from the main inlet on the roof and fed to the two cathode systems. Before the air can reach the fuel cell, it must be conditioned to remove contaminants and rainwater. So it is run through filters designed with one of the team's partners, Donaldson, before being compressed by an electrical turbo-compressor from Fisher Spindle.

Due to this compression, the air heats up so, before entering the cathode, it passes through an liquid intercooler to cool it down. Compressing the air also enables energy recuperation from the exhaust flow, which significantly increases system efficiency.

Finally, Fumatech humidifiers moisten the air so as not to dry out the fuel cell.

The compressed, intercooled and humidified air then enters the cathodes inside the fuel cell. Both cathode systems consume as much as 16kg of air per minute.

At the anode, hydrogen molecules are split into atoms and stripped of their electrons, leaving a proton that needs to pass through the fuel cell membranes. Meanwhile, the hydrogen's electron is forced through an electrical circuit. This electron movement is current that the car can use as drive power directly at the motors and power systems, or to charge the accumulator.

At the cathodes, the protons bond with the oxygen in the air and re-combine with the electron to form water molecules, which are then exhausted from the system using excess air.

Double first

'What makes the car truly unique is that it runs on two separate and independent fuel cell systems,' explains Abel van Beest, team manager of Forze Hydrogen Racing. 'Only a few experiments have been done in the past with dual-engine cars, and this is a first for fuel cells.

'Running on a dual fuel cell system like this one has several advantages. Starting from redundancy, it can help in case of a partial system failure and reduce engineering risk as one system can be developed and tested before producing the second one.' The fuel cells provide a continuous 240kW.

'The two EKPO fuel cell stacks are very power dense and are therefore a great match for a powerful, tightly packaged car,' van Beest continues. 'The two fuel cells simultaneously operate under independent deployment strategies to provide the most efficient performance for any part of a track, and allow our engineers to develop and iterate upgrades much faster.'

The total volume of hydrogen onboard amounts to about 8.5kg, which is stored in four tanks at 700 times atmospheric pressure (bar).

> **'The two fuel cells simultaneously operate under independent deployment strategies to provide the most efficient performance for any part of a track, and allow our engineers to develop and iterate upgrades much faster'**
>
> *Abel van Beest, team manager at Forze Hydrogen Racing*

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From the tanks, it is transported through high-pressure and vibration-resistant tubing from Parker to a pressure regulator that drops the pressure of the hydrogen.

The next stop is a hydrogen control system, custom developed by Forze's fuel cell engineers, in collaboration with Burkert.

This system consistently provides the fuel cell with the exact amount of hydrogen for the demand, though, in some conditions, excess hydrogen is delivered to the fuel cell to gain more performance and lifetime.

Ejector seat

A recirculation system was therefore developed using a custom component called the ejector so as not to waste the hydrogen that comes back out of the fuel cell. The ejector is a passive device used to sustain hydrogen recirculation to the fuel cell, specifically on the anode side, without power.

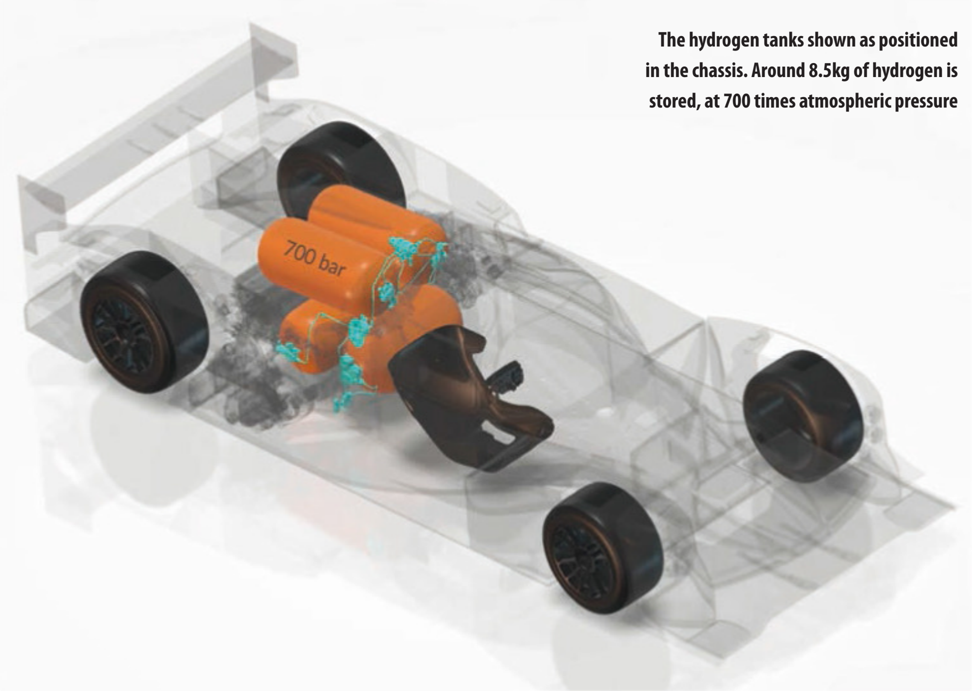
'The ejector, in essence, can be viewed as a pump, a device that increases the pressure of a fluid to overcome the frictional losses associated with mass transport,' explains India van Doornen, chief engineer at Forze Hydrogen Racing. 'Within the control of the various mass flows to and from the fuel cell, the ejector's job is to maintain the hydrogen flow on the anode side of the fuel cell, which a recirculation pump would typically fulfil.

'However, a recirculation pump requires considerable amounts of power, usually in the order of several kilowatts, to achieve the required pressure lift,' he continues. 'This power would come from that produced by the fuel cell system and is directly consumed by the systems supporting its operation, generating parasitic losses. The ejector, on the other hand, reduces the parasitic losses of the fuel cell system by tapping into another energy source: the potential energy stored as pressure within the hydrogen storage tanks.'

The stored hydrogen must be returned to near atmospheric pressure before the fuel cell can use it, and the ejector system exploits this potential energy to increase the hydrogen pressure in the anode recirculation loop. The hydrogen feed is throttled to coincide with demand, and this process is not used to produce useful output.

'The ejector increases the pressure of the gases in the fuel cell anode recirculation loop by throttling the hydrogen to a pressure several bar above the final desired pressure,' confirms van Doornen. 'The hydrogen from the storage system is accelerated through the ejector's convergent nozzle geometry, which decreases the fluid's static pressure.'

The ejector geometry means the pressure of the fluid leaving the nozzle is lower than the pressure of the fluid in the recirculation loop. As a result, the hydrogen in the recirculation loop is entrained because of the negative pressure gradient. The gases in the anode loop are therefore accelerated and mixed with the hydrogen from the storage system at a high velocity. At this point, a lot of the fluid's energy is kinetic.



The hydrogen tanks shown as positioned in the chassis. Around 8.5kg of hydrogen is stored, at 700 times atmospheric pressure

The flow is fed through a diffuser to transfer this kinetic energy back into potential energy in the form of pressure, and the ejector's geometry increases the pressure of the fluid relative to the entrained flow. Forze engineers optimised this component using flow simulations, with help from FTXT.

Racing relevance

The car features an accumulator of supercapacitor cells from Musashi, enabling onboard electrical storage with ultra-fast charge and discharge to make the fuel cell system efficient and practical for racing.

Another partner, SciMo, provides the four lightweight and power-dense electric motors that allow Forze IX to have a combined motor torque equivalent to that of a Lamborghini Huracán. The SciMo motor units also enable the Forze IX to regenerate as much energy in one braking zone as a Formula 1 car can generate in an entire lap.

'Each motor is connected to its custom gearbox and drivetrain so the wheels can spin at different speeds, allowing for torque vectoring,' explains van Doornen. 'When the car approaches a corner, it needs to decelerate. A significant part of this deceleration is achieved by regenerative braking using the four electric motors to charge the accumulator. When the car is most power sensitive, at corner exit, besides the fuel cells working on maximum power, the accumulator can be quickly discharged to the motors, delivering the total output of 600kW to the wheels.'

> **The SciMo motor units also enable the Forze IX to regenerate as much energy in one braking zone as a Formula 1 car can generate in an entire lap**

Creating a lot of power always comes with a lot of heat, since no system is 100 per cent efficient. As such, the Forze IX is heavily cooled to maintain performance. Despite the significant new technical innovations onboard, the cooling presented some of the biggest design challenges for the project.

The hydrogen fuel cell and supercapacitor accumulator run at very low temperatures compared to an internal combustion engine and, because the temperature difference between the powertrain and the outside air is small, it is hard to cool it using outside air.

Cooling package

The car is therefore fitted with five radiators spread over the car to address the cooling requirements, which the Forze team cooling engineers designed with partner, PWR. Pierburg pumps drive coolant through the system at a flow rate of up to 460l/min.

To have enough airflow through these radiators to exchange the heat with the coolant, the Forze IX needed specialised aerodynamic bodywork to accommodate its thermal requirements, while also

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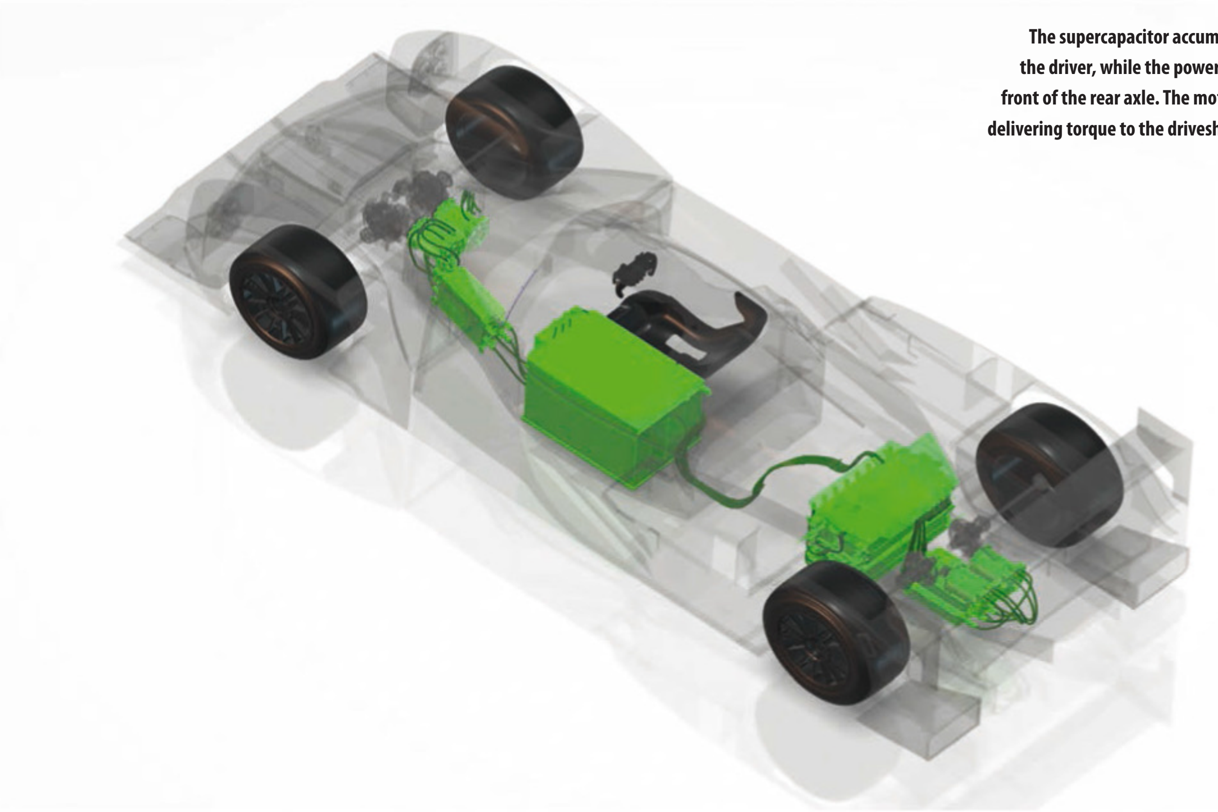


The supercapacitor accumulator is situated alongside the driver, while the power electronics are mounted in front of the rear axle. The motors sit alongside each axle, delivering torque to the driveshafts via bespoke gearboxes

maintaining adequate performance and efficiency. The Forze IX aerodynamics engineers designed the car's carbon fibre bodywork, some of which was produced in partnership with Airborne.

'The Forze IX's shape is the result of over 500 iterations of airflow simulations to optimise the aerodynamics for the application,' highlights van Doornen. 'The mass flow of air through the radiators is 190kg/min, and the Forze IX still generates 1200kg of downforce at top speed. Even with higher cooling requirements than other Prototype cars, the Forze IX has good aerodynamic efficiency with a lift-over-drag ratio of around 4:1.'

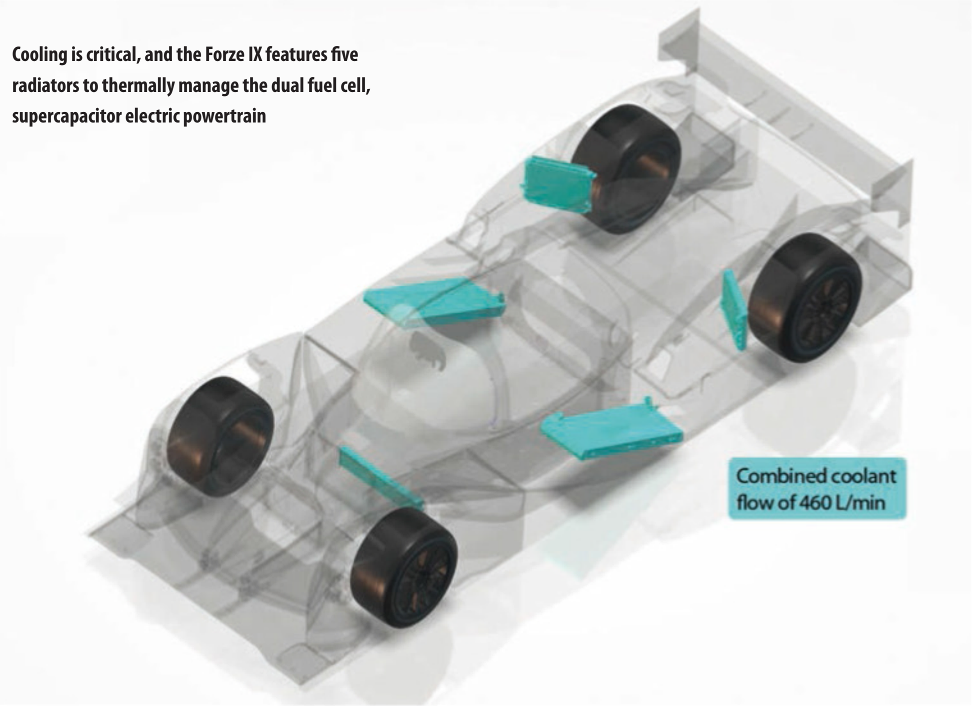
Chassis construction

The front of the chassis is a carbon fibre monocoque, built for driver and systems protection, with integrated mountings at the rear to accommodate power unit systems. The monocoque features a frontal extension to include the front drivetrain, while the back houses the accumulator and mounts for the central subframe, all while weighing just under 100kg.

The body was iterated over 300 times using various CAE solvers to ensure seamless integration of the powertrain systems.

'The central subframe mounted behind the monocoque houses most of the critical systems in the car, such as the fuel cells and the tanks,' notes van Doornen. 'It was optimised for stiffness and crash protection, while also accommodating the rear subframe mounting.

Cooling is critical, and the Forze IX features five radiators to thermally manage the dual fuel cell, supercapacitor electric powertrain



'The rear subframe consists of a structural motor and gearbox housing designed to attach to the rear suspension and a rear wing support structure to deal with those loads.'

Forze's vehicle dynamics engineers designed the double wishbone suspension.

'The tricky part about designing the suspension was the little space we had to work with in the car,' notes van Doornen. 'We needed to ensure the forces were translated properly from the ground to the chassis and provide optimal road handling while tightly packaged.

> **'The mass flow of air through the radiators is 190kg/min, and the Forze IX still generates 1200kg of downforce at top speed'**
>
> *India van Doornen, chief engineer at Forze Hydrogen Racing*

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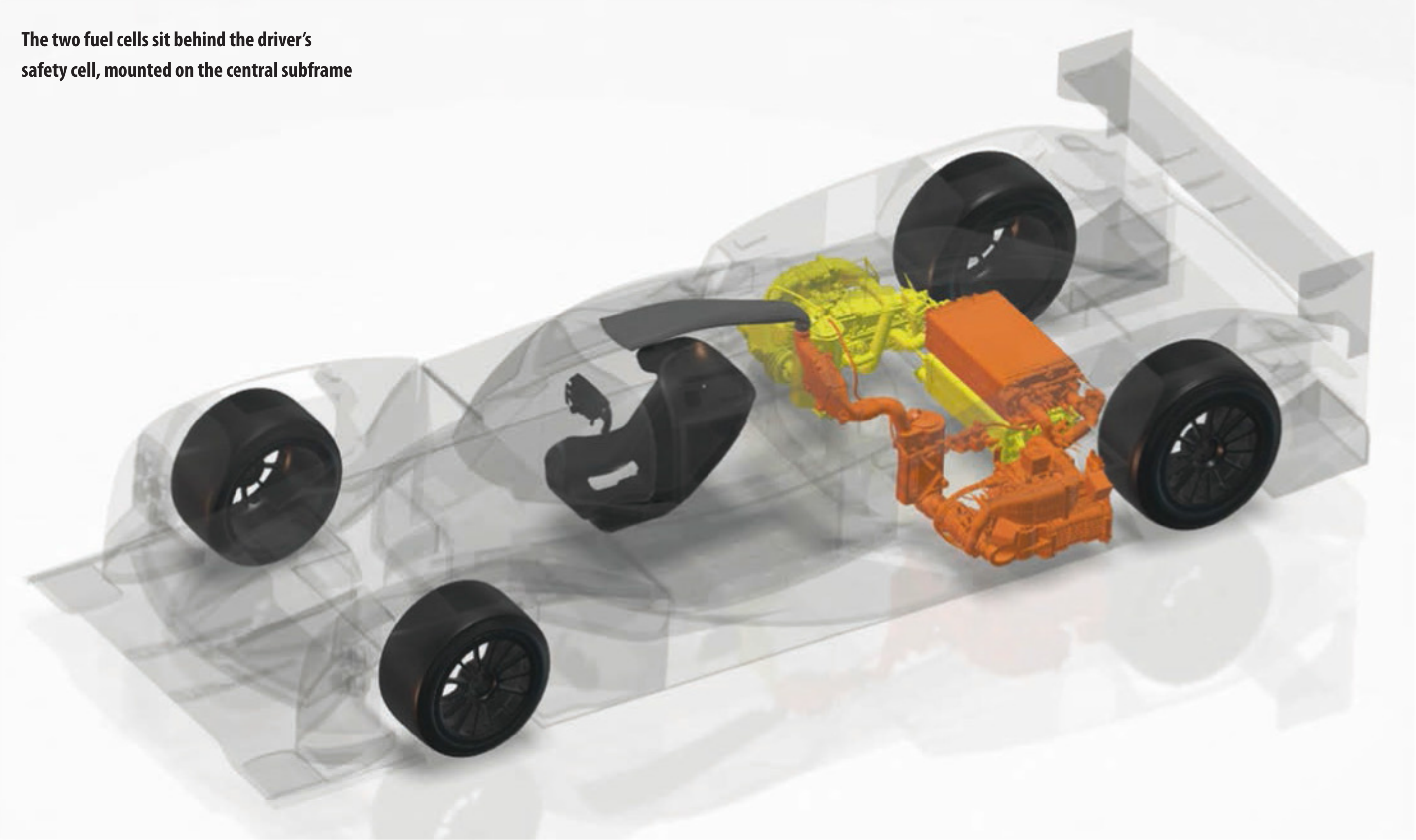

The two fuel cells sit behind the driver's safety cell, mounted on the central subframe

'Our suspension features high-quality bearings from SKF that ensure a smooth and low friction movement.'

Using driving simulations, the Forze engineering team identified all the forces and shocks occurring within the suspension while racing. A damper package from Koni was then chosen as the optimal solution for the car, providing the driver with the proper feedback from the interaction between the car and the road.

Control systems

The Forze IX is a complex machine, with a great many systems interacting, so it needed a brain to activate and accurately control all those systems. A custom power distribution system was therefore designed to manage the energy flow from the fuel cells to the four electric motors, two compressors and all other power devices.

'The function of the brain is taken up by our embedded system, which has a central processing unit and distributed sensing and activation units that operate like a nervous system,' explains van Doornen. 'All the embedded systems are prototypes, with many custom components and experimental samples from the automotive industry.'

The embedded central control systems monitor, protect and control all the sub-systems in the car. To help do this, the team developed a component called the supervisor node. This monitors the hydrogen tanks and refuelling system, checks high-voltage electronics and performs critical shutdown safely. It can take up all safety-critical features and operate them during a system failure or power loss.

The state of the car is constantly monitored by over 400 sensors provided by team partner, Kistler. That's more sensors than on a current Formula 1 car.

'The various sensors accurately measure a large variety of parameters from which thousands of calculations of the state of critical systems are made to operate the car safely and in the most performant manner,' notes van Doornen. 'Measurements of many parameters are needed to learn about the systems since the team is working with all-new technology that has never been benchmarked before.'

The team's electrical engineers have also designed custom telemetry system hardware that collects sensor data and communicates it to the central control unit of the car. From there, commands are communicated to the external hardware and relays telemetry, and to all other electrical components throughout the car when necessary.

The central control unit, which has enough processing power to run all the control systems and process all accumulated data, was designed in house and the wiring harness in cooperation with partner, Fokker. The control algorithms are written by Forze control system engineers, and dictate at all times what the controllable components in the car have to do. 'Due to its unique hydrogen electric design, the Forze IX consists of a unique collection of specialised electrical devices,' explains van Doornen. 'To integrate those into a robust and embedded system, our software engineers had to design a completely custom and extensive software structure. 'It features low-level codes to interface specific devices, and high-level implementation for system level error handling.'

As the trackside engineers also need access to all this information in order to spot any problems, or run a power strategy at a particular moment in a race, the Forze IX features telemetry using UHF, 4G and Wi-Fi systems. The car can transmit data at various rates depending on the distance from the pit wall. To make telemetry even more convenient, the Forze team, together with IBM, are setting up a cloud-based system for easy data storage and analysis.

'The Forze IX is built to keep growing and innovating, so that is what we are going to do,' states van Beest. 'In the future, Forze aims to shift towards endurance racing. We believe that is where the power of hydrogen lies.'

> **'The Forze IX is built to keep growing and innovating, so that is what we are going to do'**
>
> *Abel van Beest, team manager at Forze Hydrogen Racing*

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V V for victory

After two years of being sidelined, the ByKolles-built LMH racer looks set for a promising season ahead

By ANDREW COTTON

XPB

Denied entry in both 2021 and 2022 due to regulation technicalities and disputes over the use of the Vanwall name, the Vanwall Vandervell 680 made a strong debut at the 1000 Miles of Sebring

The flag fell at the opening round of the FIA World Endurance Championship at Sebring in 2023 with Toyota taking a handsome victory with its updated GR010. However, while Ferrari also left the Florida track happy, having secured pole position in its debut race, there were big smiles elsewhere in the Hypercar pit lane.

Jacques Villeneuve, the 1997 Formula 1 World Champion, Esteban Guerrieri and Tom Dillman brought the new Vanwall Vandervell 680 safely home at the end of a gruelling race.

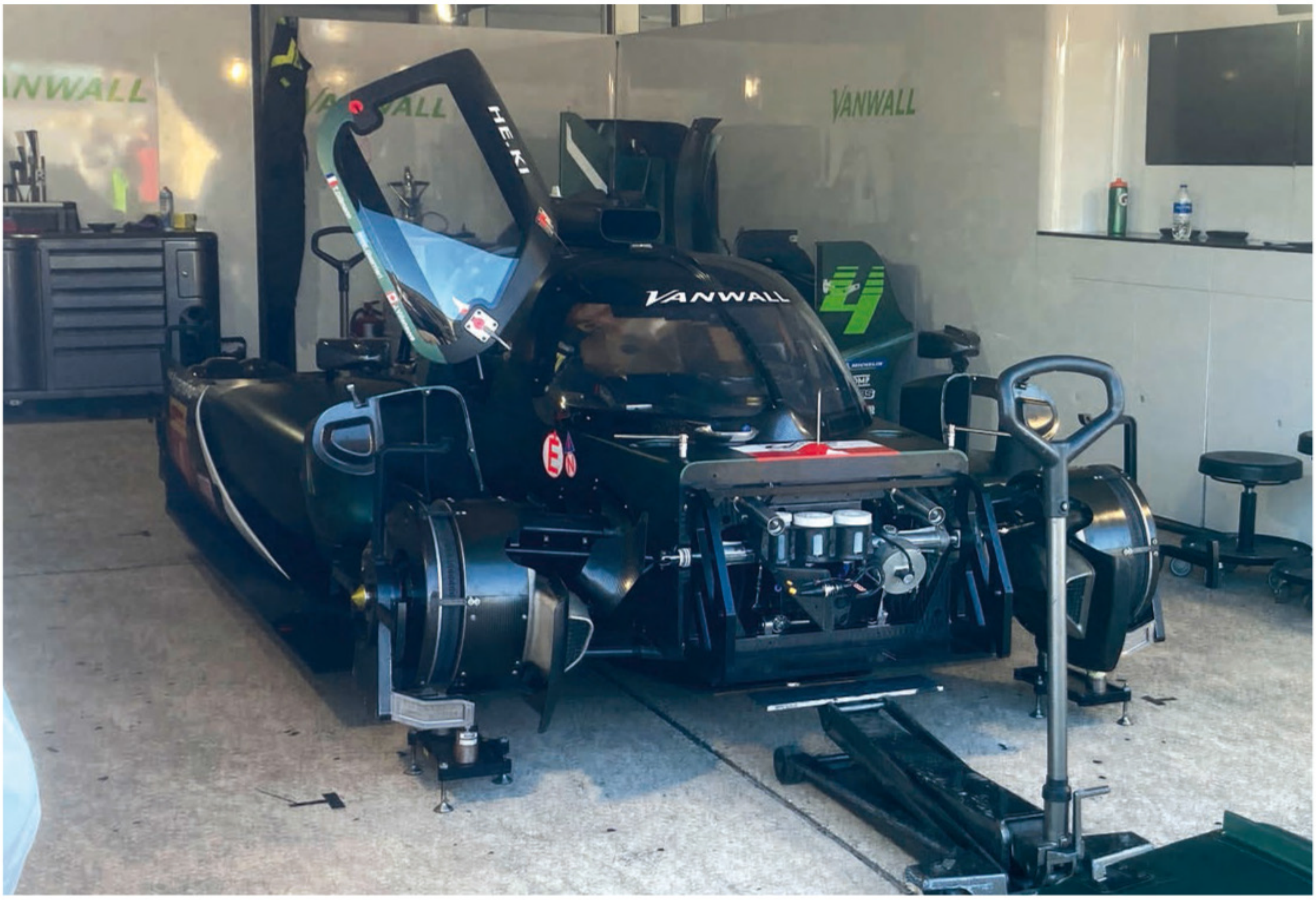
Just to get the car to the finish was an achievement, but it was made even sweeter by the fact the car performed strongly in the opening stints, and at the flag had beaten the likes of Peugeot, who already had three races under its belt ahead of the 12-hour race.

The only time the 680 lost any significant time during the race was after a rear suspension failure, likely a legacy of a heavy impact when the car was run into by a Peugeot under a safety car. The 25-minute stop to repair the rear-end damage dropped the car far down the order at the flag, but there was no question this was a strong debut.

Qualifying four seconds off the Toyota, around a 105-second lap, might not sound impressive, but the car was less than two tenths of a second slower than the Glickenhaus 007, which has raced for two seasons now, and the team had not tested before at the Sebring airfield.

Long road

It has been a long road to the grid of the FIA World Endurance Championship for the team. The ByKolles outfit ran throughout



As per LMH regulations, the car is two-wheel drive and powered by a mildly updated version of Gibson's naturally aspirated GL458 V8 engine. Built in house at ByKolles, it's a clean, efficient concept

the LMP1 era of racing using a traditional design, including a normally aspirated Gibson V8 engine, standard gearbox from Xtrac and relatively simple electronics. Under an equivalence of technology rule set, it was always going to be a tall order keeping up with, let alone beating, the big-spending factory teams of Toyota, Porsche and Audi.

However, the team continued, and when the new Hypercar regulations were announced, ByKolles was one of the first to commit, alongside Toyota. That, however, was the first mistake. The first iteration of the car was presented to the FIA at Silverstone in 2019, long before Balance of Performance was considered and approved for the top class.

Under the leadership of technical director, Boris Bermes, the team designed its new prototype to LMH regulations, the ground-up rule set that was uncompromising in its approach. However, that was at a time when the regulators were being swayed by the likes of Aston Martin, who also confirmed entry to the series with a racing version of its Valkyrie road car. Others were also in the mix, and the ACO and FIA were keen to welcome as many concepts as possible into its top class.

In order to allow in the Aston Martin, the power output of the extreme road car would have to drop to 1100bhp. To stay competitive, the power level for the prototypes increased to a similar amount, affecting the likes of Toyota, Glickenhaus and, of course, ByKolles.

Each accepted the increase in power, and ByKolles sought a new engine partner to achieve it. The Gibson GL458 V8 engine was not designed to make that kind of output, and a move to a V10 unit was not possible within the timeframe.

Once Aston Martin finally confirmed it was not coming, it was too late for the ByKolles team to finalise its design in time for the start of the new era of endurance racing in 2021, and it was forced to sit that season out. The field included Toyota, which was unwavering in its support of the FIA WEC, Alpine, who used a grandfathered LMP1 car, and Peugeot, shortly before confirming its withdrawal from the World Rally Championship with Stellantis sister brand, Citroën.

The ByKolles team needed time to finalise its design and bring it to the track. However, there was a further fly in the ointment. The WEC's sporting regulations mandate a relationship to a road car manufacturer. There is no logical reason for this, but teams signing up to compete must comply with the regulation. Colin Kolles is currently involved in a legal argument to use the name Vanwall, and homologation issues with the road car being produced under the famous banner – a street-legal version of the LMH car, of which 500 will be built – forced the team to sit out the 2022 season as well, to the fury of the team and team owner.

Debut season

Nevertheless, the team had its entry accepted for 2023 and so the car was finally able to make its debut at the 1000 Miles of Sebring in March.

On the surface, the Vandervell Vanwall 680 is a straightforward racecar. Like its rivals from Glickenhaus, the design team opted to compete without a hybrid system, which immediately reduces both cost and complication. Not having a hybrid system also means the car is two-wheel drive, with

The design team opted to compete without a hybrid system, which immediately reduces both cost and complication

just the rear wheels being powered by a Gibson GL458, normally aspirated V8 engine.

The engine did need a little update as power to the LMH non-hybrid car is limited to 500kW and hitting that target power has meant the Cosworth ECU has to work a little harder. A giant air scoop over the cockpit feeds the required large volume of air into the engine.

'It was the most useful solution,' says the team's technical director, Boris Bermes. 'It is an NA engine, so you need quite a lot of air, not like a turbo. This was just a logical design.

'There was further development of the LMP1 engine, adapted to the torque control, so just a smaller modification to match the regulations, but that was just little things.'

F1-style

The team has leaned heavily on Formula 1 philosophy in the design of the car, and even Formula 1 technology in places. The Xtrac gearbox casing is designed by the team and Bermes says the internals have been tailored to the car's needs.

The tiny radiators housed in the sidepods are from Australian company PWR, and are essentially fettled F1 radiators.

'Radiators at the side is also F1 style,' says Bermes. 'The profile is quite a complicated shape and the sidepod has an undercut like Formula 1. It is F1 technology, but we are not doing our own development. We get a b-spec radiator, so it needs development, but it doesn't have to be done from scratch.'

It's the same with the front brakes, which are from AP. Airflow to the brakes comes through the wide, open nose of the car, and brake duct shaping is clearly inspired by Formula 1 practice. Others have closed off the area around the brakes, and feed through the bodywork, but the prototype design team has gone its own way.

'You can see many others are taking brake cooling air from the bodywork, but ours is like F1-style, and even in LMP1 they take the air through the nose,' says Bermes. 'It's quite open at the front and it is a different concept, which is what the regulations wanted; to keep it open. All of this is aero driven.'

Small windows

That might seem to be a strange starting point, given the cars are performance balanced into a small window of lift and drag. In all attitudes and set-ups the car has to remain within this window of performance, which is one of the biggest headaches for the design teams.

'The aero window is quite small, not that difficult to reach, but to remain in that window is very sensitive,' says Bermes. 'Small bits can change, and then you jump out of the window. So, you have to prepare your car with small parts that you can tune to remain within the window. This is the main principle on the aerodynamic performance.

'Building a car from scratch is always difficult and a big challenge for everyone. It is not that easy. The window numbers in terms of efficiency are not so difficult to reach, but it is a big job to then keep the car in this area.'

The team has leaned heavily on Formula 1 philosophy in the design of the car, and even Formula 1 technology in places

The team is famous for building and preparing its own cars, and this one is no different. Such an approach allows the team to retain full control over all aspects of the design, and the result is a clean, efficient concept.

Like its competition, the team worked through the options for trimming the car. Under the regulations they can choose either a front or a rear-adjustable device, and opted for the rear wing.

'We had both options, tested both on track and wind tunnel and went to the rear,' confirms Bermes. 'It was aero driven, and we considered it to be the better solution.'

The team clearly has a long way to go in order to hit Kolles' stated aim of winning races, and in the face of such competition it's again a tall order. However, you have to be in it to win it, and once again his team is on the FIA WEC grid.

VANDERVELL 680
Floyd
Visit Argentina
DHL
4
HYPER CAR
MICHELIN

XPB

Side-mounted radiators in undercut sidepods and airflow to the brakes fed through the nose of the car are all borrowed from contemporary F1 practice. Both concepts are said to be aero driven

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YD63
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28

Autograss cars are designed to make the most of the standing starts, where a race is often won or lost. With a large rear weight bias and plenty of power, front ends often lift high when the clutch is dropped

Super 'Grass

The top cars are capable of sub-2.5s 0-60 times, with power-to-weight ratios around the 1000bhp / tonne mark, and carbon fibre is banned because the cows might eat it. Welcome to the wonderful world of Autograss

By MIKE BRESLIN

H250
SIMPSON

Paul Rudduck/PR Photography

Forgive the pun, but it doesn't get more grassroots than Autograss. This is motorsport at its most accessible, with a wide range of classes to suit every budget and plenty of meetings taking place across the length and breadth of the UK.

But just because it's easy to become involved doesn't mean it's simple to succeed, as the racing is ferociously competitive, while there's also a peculiar technical challenge that would test the skills of any racecar engineer – which is largely about nailing the starts… made on slippery, loose surfaces.

But before we get to the starts, let's go back to the start. Autograss grew out of 'Jalopy Racing' in the 1960s – basically oval track racing in farmers' fields. Then, in the 1970s, the disparate clubs came together under the auspices of a governing body, NASA (National Autograss Sports Association).

It would be lovely to say Autograss rocketed into the national motorsport consciousness from then on, but it's always kept a low profile. Despite this, the sport is remarkably healthy, with over 3000 licence holders in the UK and up to 600 entries in the flagship British Championship events.

There are 10 classes in Autograss (plus classes for juniors), all of which feature two-wheel drive cars that race in a number of heats to qualify for a class final. Class 1 is for standard front-wheel drive under 1000cc; Class 2 for near-standard under 1300cc; 3 is rear-wheel drive with bigger engines; 4 is 1130cc maximum with unlimited modifications; 5 is open but the engine must be between 1131 and 1420cc with only two valves per cylinder, while 6 is pretty much anything goes, provided it's front-wheel drive.

But for the purposes of this feature, we will concentrate on the quickest cars of all.

These are the Class 7 unlimited super saloons and the Specials classes: 8, 9 and 10. All cars competing in these are capable of reaching speeds around 100mph on the quarter-mile oval tracks.

'The Specials are Class 8, the under 1420cc class; Class 9 is under 2.0-litre, and Class 10 is anything goes, which is the same as the super saloons [Class 7],' explains Chris Allanson, a ground-breaking car builder and veteran 'grasser', as these racers call themselves, who is also on the NASA board of directors.

While it is perfectly possible for people to build their own cars for even the top classes, and some do, many buy choose to buy them from one of the established Autograss chassis manufacturers such as Xtreme Race Cars or Xcworx Chassis Developments. New Class 8 cars cost around £25,000-£30,000 (approx. $30,500-$36,700), depending on spec.

To give an idea of the size of the market, Russ Shepherd, who owns Xtreme Race Cars, sells around 15 to 20 cars a year, while Allanson says confidently: 'There's going to be 100 brand new cars out there this year.'

Design philosophy

While the top classes do differ, there is one crucial aspect each car design must address.

'Realistically, 80 per cent of the race is from the start to the first corner,' says Wes Green, who works on the race team at Red Bull in F1 when he's not racing his Class 8 Special.

'If you can get to the first corner first, 80 per cent of the work is done. It's hard, because we're oval racing, but to be quick you need a drag car, and drag cars don't go around corners. So it's a compromise between building a drag car and an oval racing car.'

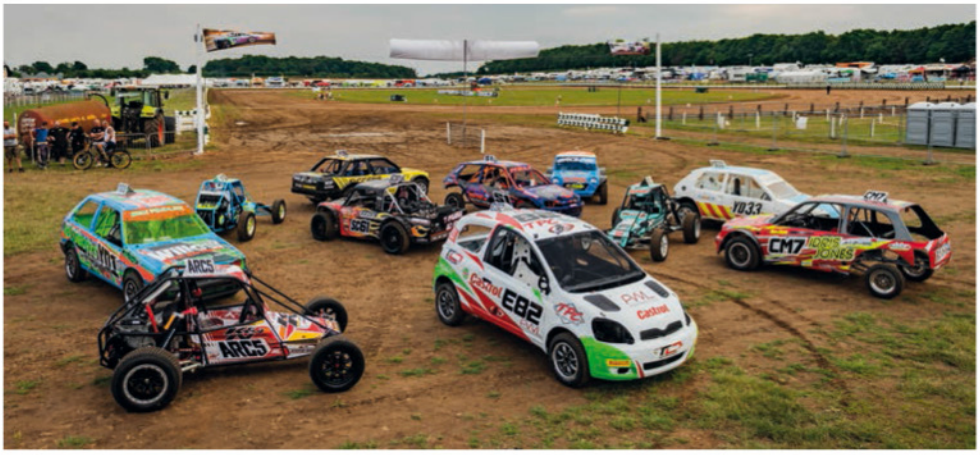
The reason a drag car is needed is because of the standing starts. With up to eight cars lined up side-by-side, it's this that sets Autograss apart from other oval categories. And from drag racing for that matter.

'We can't just set the cars up as in other oval formulae, because they have a rolling start and we don't,' says Shepherd. 'There's quite an art to getting an Autograss set-up right. You need maximum traction in a straight line, but this then means you can't have a car which is offset, with loads of inside weight to get it through a corner.'

While it would be wrong to say that the cars are solely designed to get off the line well, as there is certainly overtaking, this definitely dictates the overall technical philosophy, with heavy rear-weight biasing being order of the day – around 70 to 75 per cent to the rear in the top classes.

The need for blistering acceleration has also resulted in extremely light race cars.

'The lightest cars now are Class 8, and that's the most competitive class, with the most drivers in it,' confirms Shepherd. 'The cars in that class can be as light as 310kg.'



Paul Rudduck/PR Photography

There are a wide variety of classes ranging from standard to hi-tech Specials. Check out S1 and CM7 for good examples of ultra-light rear ends in the modified front-wheel drive cars

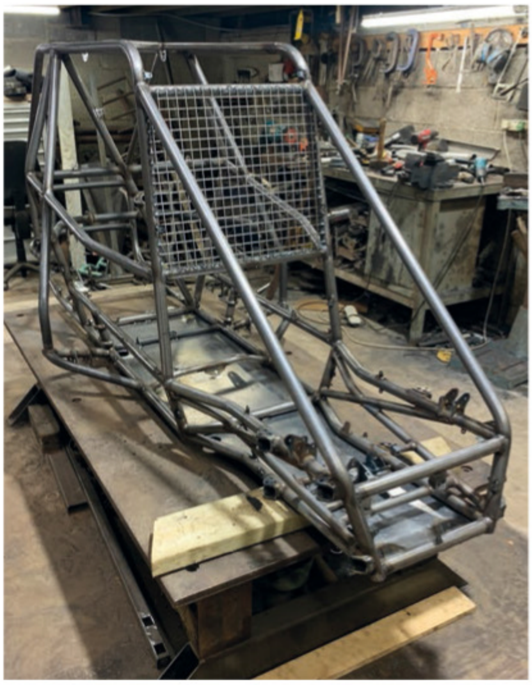
The drive for lightness starts with the chassis itself, which in the quicker classes are spaceframes with integrated roll structures. They're mostly built from CDS tubing, though in some cases and places T45 is used. The bare chassis can weigh as little as 75kg, we're told, though safety is never compromised.

'We have quite a strict rulebook, for the width of cars and the amount of bars you have to put in,' Shepherd continues. 'Which is why the [Specials] can all look the same, at least to the average spectator.'

Green, who has developed his own car, actually built his spaceframe so the outer rails, on the left, are slightly longer than those on the right – one of the few nods to asymmetry available in this category.

'We run the wheelbase a little bit longer on the outside of the car,' he confirms. 'That helps with the fact that we race on an oval track, but there's a limit on how much you can do that because, obviously, you don't want to affect the starts.'

Aerodynamic add-ons like wings are forbidden, and what little bodywork there



The Specials are built around lightweight steel spaceframes to strict safety standards, which call for an integral roll structure plus a steel mesh anti-intrusion 'windscreen'

To counteract the inevitable understeer because of the rear weight bias and locked differential in the Specials, an attacking driving style is required, so there's plenty of lock in the steering

Paul Rudduck/PR Photography

Paul Rudduck/PR Photography

WR20
Stephensons
TT

Mini pickup-style bodies are the car of choice in Class 7. These are clad in steel panels, but are otherwise very different to the original car – sitting over a spaceframe chassis and often packing twin motorcycle engines in the back

Wes Green's car has a BMW S1000RR motorcycle power unit, which revs to 15,500rpm. The other popular engine in Class 8 is the 1340cc Suzuki Hayabusa motor, while car engines rule the roost in Class 9

'You need maximum traction in a straight line, but this then means you can't have a car that is offset, with loads of inside weight to get it through a corner'

is on the skeletal-looking Specials is steel, chiefly because carbon fibre, Kevlar, GRP and the like are banned. This is not a cost saving measure, as might be assumed, but a bovine life saving measure, as Allanson explains:

'You're not allowed carbon, or glass fibre, because if you smash it up and a cow eats it, it could kill the cow.'

This is a throwback to the time when races were held on farmers' fields, but the ruling still stands, even though most tracks are now permanent, as they're often dual purpose. Farming is all about diversification these days.

For this reason, the silhouette-style spaceframe Class 7 super saloons are not draped in GRP 'shells, but fitted with close to original looking steel panels. Most of these are now Mini pickups, which have a short wheelbase to help with those all-important starts and are also very light.

'There's a company called Magnum Panels,' says John Gay of Xcworx, which builds both Specials and modified saloons. 'They supply all the panels – wings, bonnets and door skins for Mini pickups. And then there's a couple of companies who make the pickup panels for around the back.'

In Class 7, you are allowed to put the power unit in the rear of the car, and one of the advantages of the Mini pickup as a body shape is it offers a natural space to place an engine. Or even two…

Power units

Class 7 cars have been running with twin engines since the 1990s, and Allanson was the first man to do it.

'In 1995, I built the first twin bike engine car,' he says. 'That's two engines driving either chains and sprockets or a gearbox on to a single axle. If you put two tuned [Suzuki] Hayabusa engines in the back of a Mini pickup, you end up with something that weighs probably 540kg but has 500-600bhp.'

Do a quick bit of mental arithmetic here and you'll get a mental answer, too. How does around 1000bhp per tonne grab you?

While the idea of fitting two bike engines into a car sounds radical, it is in fact quite straightforward, as Shepherd explains: 'They use the original output sprockets of the engine(s), and generally we make a drive unit to connect the two together.

'Basically, you synchronise the gear changes through one gear stick,' adds Gay. 'That's straightforward, as long as you get all your geometry right on the gear linkage. Then you just balance the throttles, at about 6000rpm on a twin 'Busa. Once they've bedded in, you very rarely have to re-balance them after that.'

Some of the Class 10 Specials also use twin bike engines, amongst other options, but in Class 8 – arguably the quickest cars because of their light weight and better handling – the most popular option is a single 1340cc Hayabusa unit, though BMW's 1000cc S1000RR power unit has been gaining in popularity more recently.

As with all motorsport, engine choice comes down to weighing up the pros and cons. 'The Hayabusa is 20kg heavier than the BMW,' notes Green, who uses the latter.

Paul Rudduck/PR Photography

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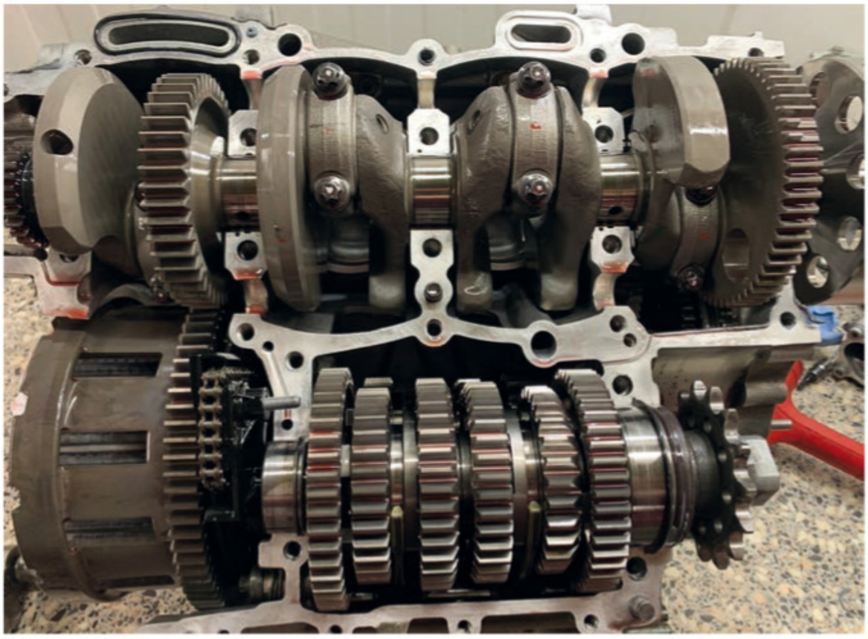
S1

Chevrolet V8 crate engines have proved very effective in Class 7. While they might be a little heavy, their high torque output makes them ideal for use in Autograss

'With a bike motor you might be constantly rebuilding the engines, but with a Chevy [V8] you could chuck a bucket of sand down the inlet manifold and it wouldn't make a lot of difference'



F1 transmission man, Wes Green, has developed a gearbox that features a choice of two starting ratios and of four second gears, which is what is used in a race. This gives him numerous options on the changeable track surfaces

'Our engine is more powerful than a Hayabusa, but doesn't have the torque. But then ours is revving to around 15,500rpm and a 'Busa revs to 10 and a half. Having more rpm does kind of overcome the lack of torque.'

There is also plenty of scope for tuning in Class 8, which adds another dimension.

'We can do basically whatever we want, as long as it remains naturally aspirated,' says Green. 'So we run different camshafts, we've done work with valve springs, we've tried high compression pistons. It's endless. We can do quite a lot really.'

The power from each installation will differ, but ballpark figures of around 230bhp are given. Which, when the light weight is factored in, means something in the region of 750bhp / tonne, and a 0-60 of around 2.5s.

In class 7 and 10, the Hayabusa units are often bored out to 1.6-litres, which goes some way to explaining the mad power available in some of the twin-engine cars.

But going in an different direction, Chevy V8 crate engines are also very competitive, and becoming increasingly popular. 'It's a totally different type of car to race,' says Gay, 'as you're using the engine's torque.

'With a bike motor you might be constantly rebuilding the engines, but with a Chevy you could chuck a bucket of sand into the inlet manifold and it wouldn't make a lot of difference. Chevy V8 is cheap power. You just buy a crate engine, do a few basic things to it, and off you go.'

Transmission choice

A wide range of car engines – Ford's Duratec and Honda's Type R are popular in Class 9 – means a wide range of gearboxes are used too, including familiar names from the racecar world like Hewland, Sadev and Quaife. In the case of bike-engine cars, the original gearboxes, or modified versions of these, are the preferred choice.

'In Class 8, you tend to take out the original six speeds and then we have a three or four-speed version that goes in, where the ratios are a lot closer together,' says Shepherd. 'You gear it so that when there's grip there, second will work. But when the grip starts to go you can adapt to the conditions.'

Into gear

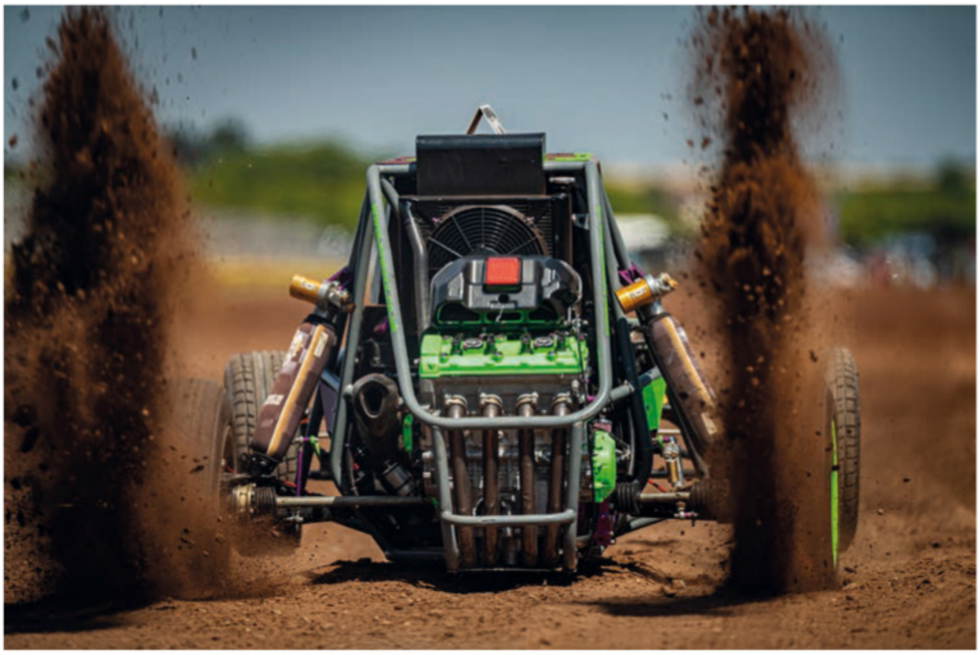
It's important to note here that, once the car is in its race ratio – normally second – it will stay in that gear for the duration of the race, unless something unexpected happens.

Being Max Verstappen's gearbox mechanic, it's no surprise to hear that, together with his father, Graham, Green has developed his own 'box for Autograss racing.

'It has six gears,' he explains. 'We have two options of start gear, dependent on track conditions. The grip levels can vary massively, and at very short notice, and you need to be equipped to deal with that. This new gearbox gives us a lot of options.

'Essentially, we have two start gears, two different ratios. We've then got four second gears that are all at small intervals. So you can work the engine in the window you want it to work in. It gives us the variation to be able to be as quick as we can be in as many conditions without changing anything.

'But with these bike engines, especially the BMW, the gearboxes are so small it's ridiculous. Let's just say it's been a bit of a challenge getting it all to fit.'



Paul Rudduck/PR Photography

Effectively drag racing on dirt requires a very specific set-up and so suspension development, along with light weighting, is at the heart of the technological battle in the Specials classes. Note the small shock, mounted quite high, and the long springs evident here

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With a locked differential and a massive rear weight bias, it's no surprise these cars naturally understeer. Which, ironically, is what makes them spectacular to watch.

'To get it to turn, you just chuck it at the corner, keep on the power and slide it, a bit like a Speedway motorbike.' Says Allanson. 'You cope with understeer by driving around it. But put somebody in it that didn't know what they were doing and they'd probably understeer into the fence at the first corner!'

Because of this sideways style, the steering has a huge amount of lock, with front wheels often seen at right angles to the chassis. Driving them is quite a challenge then.

Sideways isn't always the way to go, though, explains Gay: 'When the track becomes polished, that's the *wrong* way to drive. Then you need to be smooth.'

One thing circuit racers do not need to know how to handle – unless things have gone drastically wrong – is wheelies, which are an occupational hazard in Autograss, much to the delight of spectators.

While the cars will lift their noses along the straights and out of corners on the throttle, most front-end lifting occurs at the start, and balancing this is part of the art for a grasser.

'You try to get it so that it will just be lifting,' says Shepherd. 'So, when you drop the clutch, if you can get it so the front wheels are just hovering, you've got maximum traction.'

Suspension path

To get that demon start you need a set-up that allows weight transfer longitudinally through the car, yet you still need to go around the corners. Suspension is thefore the major development path in Autograss, with some fairly hi-tech systems in use. That said, most of the top cars use the well-proven technology of trailing arms at the back and double wishbones at the front, with dampers and springs usually outboard on the Specials and quite high at the rear – often with short, light shocks working with long springs.

On track, the cars look quite soft, which is partly to do with weight transfer off the line, but also because this is still off-road racing.

'Although they try to make the tracks as smooth as possible, they are still a little rough,' notes Shepherd. 'And if it's hard suspension, what tends to happen is the wheels don't follow the bumps, which means they are jumping in the air all the time and you're not getting traction. They are really soft, vs a circuit car, but for that reason: traction.'

Consequently, dampers have been a major area of development in recent years.

'The main shocks people use are from a company called Xtrax, who make shocks just for Autograss cars. They are three-way adjustable, as in high and low-speed bump and rebound. And then you've got dampers like Öhlins or Penske,' says Shepherd.

'With the light weight comes development of the suspension, to make the tyres work as hard as possible. There's a lot of development using different spring set-ups, different shocks and valves, and internals in the shockers,' says Green, who uses a damper set-up that's been optimised to help solve the drag car vs oval car conundrum.

'We run a Reiger suspension with CCV, a control valve, a bit like what WRC cars use. It's basically a fourth adjustment that controls the damper when the car rolls. If the car rolls, it then depends on how you've got it set up and valved, so it then depends on how much the car is loaded. Essentially, it works like a roll bar, but is a lot more efficient. You can run the car a lot softer to get a better drag car, and then as soon as the car is loaded it stiffens itself up, so you get the rotation for the corner.'

Brakes aren't so crucial in Autograss. Some use motorcycle calipers with small discs, and where they are used to good effect is for putting weight onto the front on corner entry.

'It's mainly just a small dab of the brakes, to transfer weight onto the nose, so you can then control it.' confirms Green.

Practice? Nah

Another peculiar technical challenge is the lack of testing, practice and qualifying laps. The start is literally that in Autograss.

Also, while most tracks are now permanent, they are nothing like a tarmac oval, or even a shale track. The surface is extremely changeable, often due to water bowsers being used to reduce the dust.

'Our sport is odd,' says Allanson. 'You pull up to the start line after the water bowser has gone around the first corner. You don't know where the hell he's dropped the water, you just have to barrel into the first bend and sort it out when you get there.'

The diverse selection of cars that will race during a meeting also adds to that first corner uncertainty. Because of all this, the drivers need to rely on their car control and reactions when they hit that crucial first turn.

> **'To get it to turn, you just chuck it at the corner, keep on the power and slide it, a bit like a Speedway motorbike'**

On the engineering side, there's much that can be altered in the car to adapt to the ever-changing conditions.

'We have an adjustable wheelbase,' says Shepherd. 'We can slacken off four bolts [at the rear] and slide the wheels backwards or forwards to make it longer or shorter. We have 45mm of travel there. If you move the wheels forward, it gives you more grip, but then the car is more likely to wheelie. You really need to get that bit right.

'Ultimately, you try to set the car up so that in most conditions you might be running two or three kg [of ballast] in the front. And then you've got the option, when the grip goes, to take the ballast out. You can also alter your roll bar, and mess about with your shocks. So you've got four main things you can alter on the day to get your car working right for the track conditions. Plus, you can change your gearing, and people also change tyre sizes to alter that.'

Those tyres are cost-effective remoulds, supplied by Maxsport, and while top line drivers get through them quickly, they're a hard enough compound that those racing on a tight budget can make them last a season.

But while budgets are always important, we're guessing it's the technical freedom in the top classes of Autograss racing that will interest most *Racecar* readers.

'It's always fitted my ethos,' Allanson says. 'My thing is I like to be the constructor *and* the driver. To me, the big, big draw of grass track racing, even now at 65 years old and having built hundreds of cars, is looking for that little thing to make the car faster.' R

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While wheelies are spectacular, 'grassers' work hard to keep them to a minimum, even sometimes running with a little ballast in the front when the grip level is high

Paul Rudduck/PR Photography

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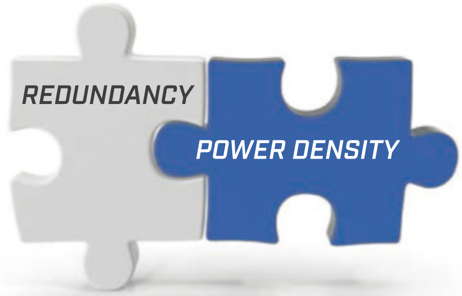

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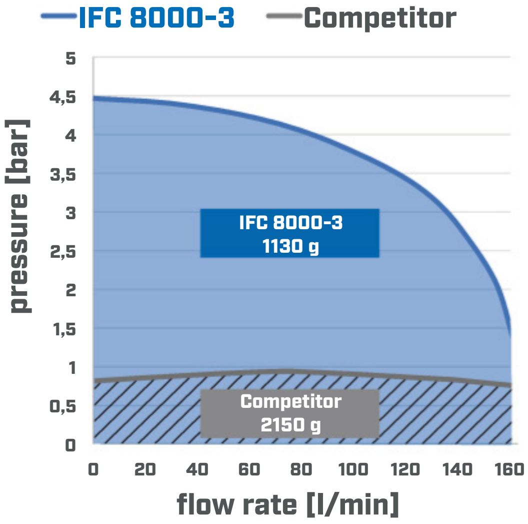

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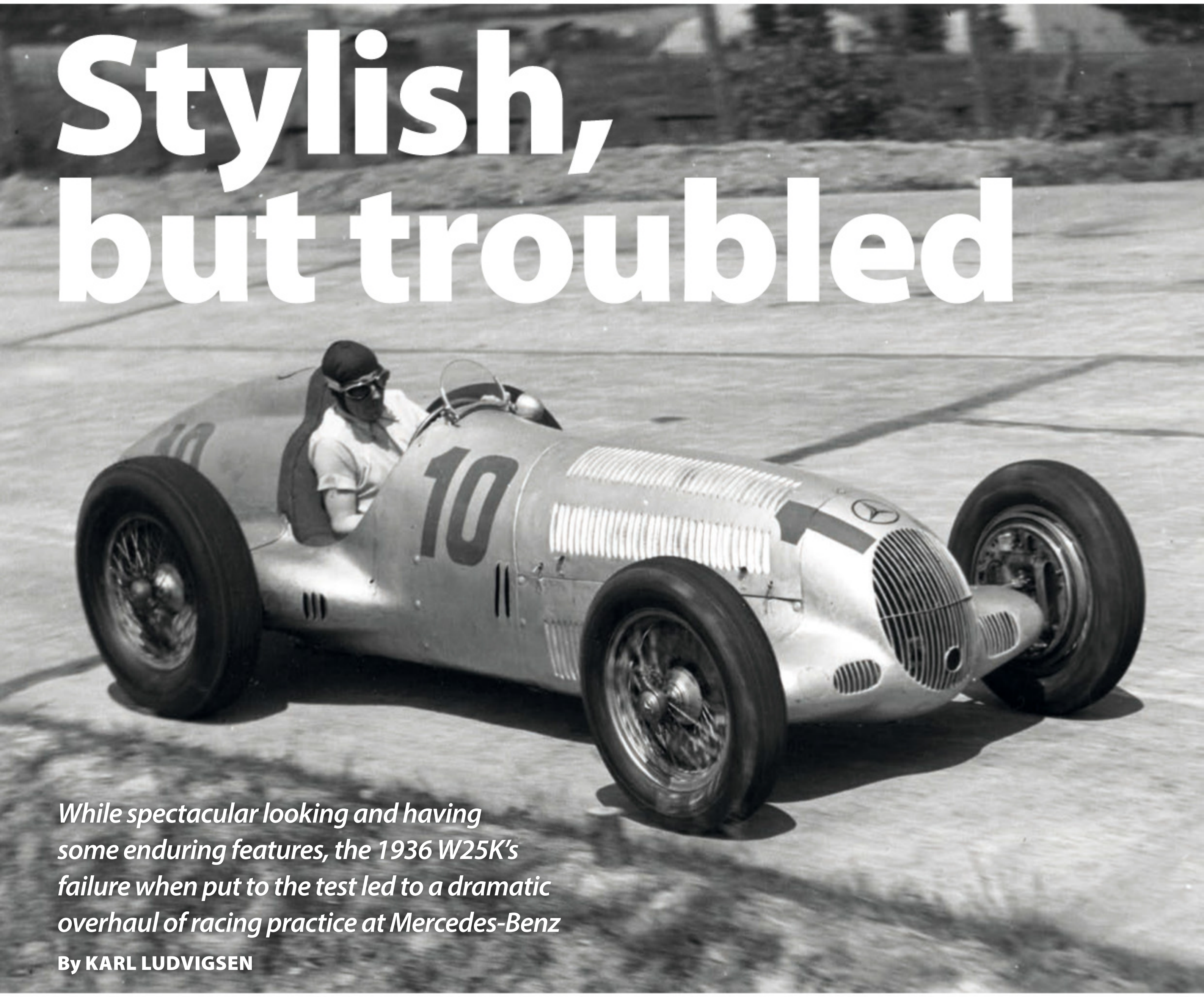
Stylish, but troubled

While spectacular looking and having some enduring features, the 1936 W25K's failure when put to the test led to a dramatic overhaul of racing practice at Mercedes-Benz

By KARL LUDVIGSEN



Pictured during training at the Nürburgring before the Eifel race of 14 June 1936, the new W25K (here with Manfred von Brauchitsch driving) was arguably the most attractive racecar yet built

Images: via Karl Ludvigsen

The year 1935 provided an excellent grand prix season, the best that Mercedes-Benz enjoyed against strong and varied opposition in year two of the new 750kg GP formula. In its second season, the W25 was fully proven and raced as part of a group that was at last operating as a team, driven by two absolute aces in Rudy Caracciola and Luigi Fagioli.

Caught napping by the Germans, who had been quicker to see the potential of the new rules, Alfa Romeo and Maserati introduced new and faster cars in 1935 that threatened to be sterner rivals in 1936. And the meteoric Bernd Rosemeyer was displaying uncommon skill at the wheel of his Auto Union. Major changes in the Mercedes-Benz equipment for the formula's third year were clearly needed.

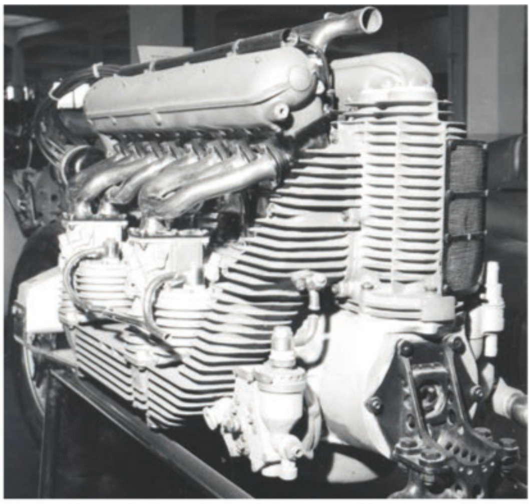
For 1936, the plan was to build an SSK version of the W25, a car that would be lower and shorter, especially at the rear.
The reduction in size would make the car inherently lighter, so it could be equipped with a new and more powerful engine without exceeding the weight limit.

DAB hand

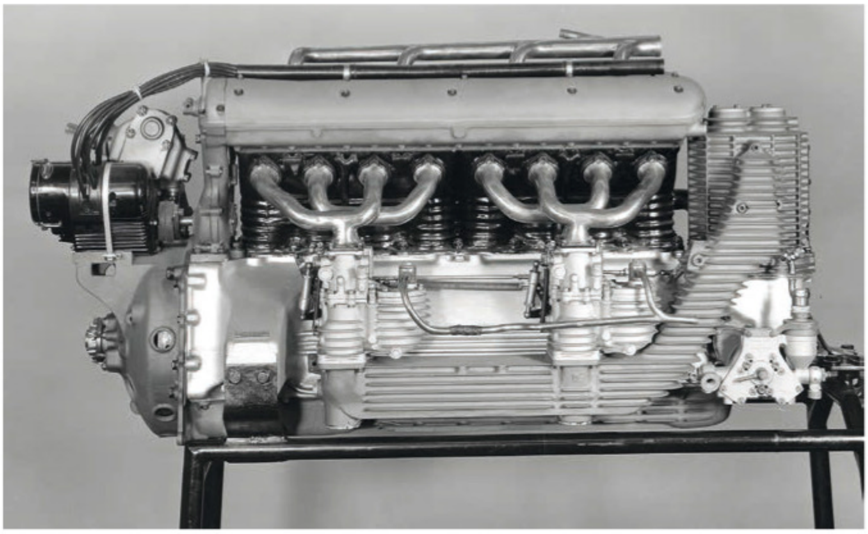
Conceived for this purpose by the Albert Heess engine group was a 60-degree V12 using the same construction techniques as the M25 eight. Cylinder blocks were welded steel with integral four-valve-per-piston heads.

The first of these D-series engines was designated DAB because they had the same dimensions as the latest eight, the M25AB, 82 x 88 mm for 5577cc (340ci). The design office estimated it would deliver 516bhp on 2B fuel, the usual racing blend, and 598bhp on WW, or pure alcohol.

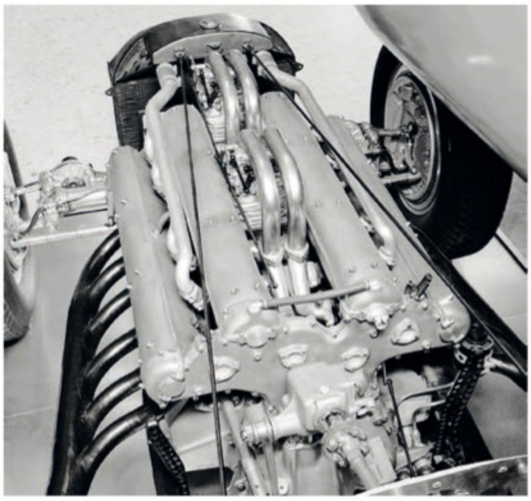
> **'Although the new car was within the 750kg limit, [with the V12] it had too much weight at the front end. It was quite good for setting records on a straight road but quite unsuitable for the Nürburgring'**
>
> *Rudolf Uhlenhaut, engineer at Mercedes-Benz*



Mercedes-Benz relied on delivering compressed air to the dual carburettors that then fed the cylinders. In the M25 engine series, the delivery channels were heavily finned for cooling



The Mercedes-Benz engineers built a bigger version of the proven M25B straight-eight engine for the 1936 season. The new, 4.7-litre ME25 produced between 450 and 470bhp, depending on whether a 240 or 255mm blower was fitted



Pictured in a W25K chassis, the DAB V12 was intended for grand prix racing, but its weight was too much, and its positioning too far forward, for good handling. Its true calling was record breaking

In late summer of 1935, the first DAB engine was found to be disappointing, not in its power but in its weight. It scaled 650lb (295kg), almost 250lb more than the various M25 eights. This only confirmed that the steel cylinder construction, so suitable for the straight eights, was inappropriate for a V12. After this discovery, dynamometer development of the DAB engine was slowed.

Nevertheless, an early test report from 1936 showed it developed 570bhp at 5500rpm, close enough for comfort to the design office forecast.

In spite of the V12 engine's heft, it was installed in a new 1936 chassis to find out if the resulting racecar could be under the weight limit. Engineer, Rudolf Uhlenhaut, said it could, but it was not well enough balanced to be a successful road racer: 'Although the new car was within the 750kg limit, it had too much weight at the front end. It was quite good for setting records on a straight road but quite unsuitable for the Nürburgring, for example.'

Straight to the eight

Switching to a straight eight would be the solution. Jumping to the next letter of the alphabet, a decision was taken in mid-September 1935 to build an E-series engine, altering the letter / number designation sequence to make it the ME25.

By the end of November, the Heess staff had completed work on this final expansion of the original M25 engine within its 95mm cylinder bore spacing. Stroke, crankshaft, connecting rods and bottom end generally remained at the maximum to which they had already been stretched in the M25C, while the bore was enlarged by 4mm. Its dimensions were therefore 86 x 102mm for 4740cc (289ci).

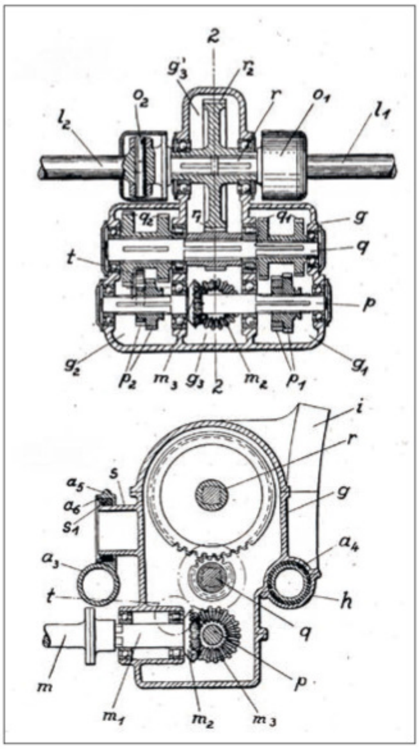
New cylinder forgings for this larger bore engine allowed a valve size increase to 37mm.

A new supercharger was designed with an enlargement in rotor diameter from 106 to 125mm. Blowers of both 240mm and 255mm rotor lengths were prepared, the smaller one considered the standard size. They continued to use steel rotors while experiments with light alloy rotors proceeded.

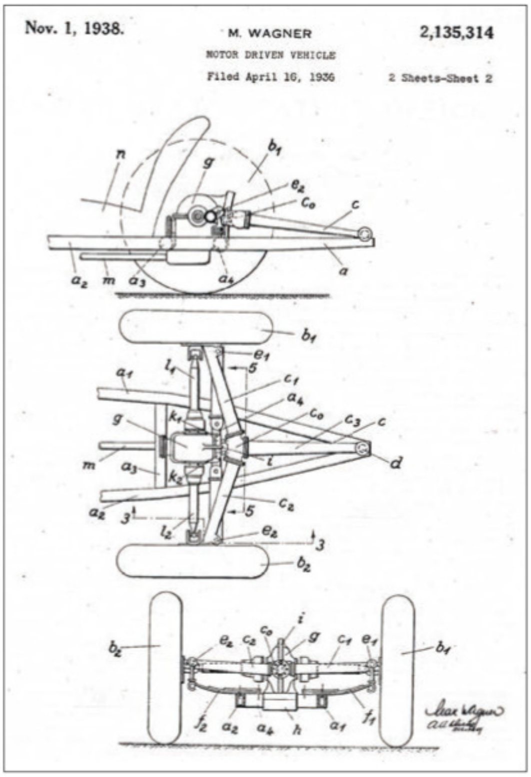
New, larger 36mm intake manifold sets were also readied for the ME25. The blower boosted through two carburettors and manifolds were available in different diameters to tune the cars to specific circuits.

Orders were issued for the production of six of these new engines, along with six spare crankshafts, the parts to be ready on 20 January 1936, with dynamometer testing scheduled to begin on 15 February. Though a late effort with a high element of risk, it was the only course open to the team.

A later increase by four brought to 10 the total of ME25 engines built. While, as a back-up, all the available M25B and M25C engines were also made race ready for the 1936 season.



Chassis engineer, Max Wagner, oversaw this revolutionary new transverse-shaft transaxle for the W25K. An antiquated characteristic was its use of sliding gears to select ratios



Another Wagner innovation for the W25K was the rear suspension, often incorrectly referred to as a de Dion tube. He patented its design with a pivot point at the tail and quarter-elliptic rear springing

M25C power units were used in tests to propel the first of the five new 1936 racecars that were built, called simply Model 1936 or, more familiarly, 'the short car'. The author prefers to use the suitable designation of W25K instead.

Two chassis were assembled and two were in component form by early October 1935 when testing began.

Team players

Ex-Benz man, Max Wagner, continued to direct the chassis design side, directly under chief racing engineer, Max Sailer, and his still youthful deputy, Fritz Nallinger. Seconded to Alfred Neubauer's Sports Department to give liaison and technical assistance was an Untertürkheim veteran, ex-riding-mechanic Jakob Krauss.

The W25K incorporated several significant changes. Its wheelbase was shortened by more than 10in to 97in, though front and rear track remained the same at 58 and 56in respectively. The reduction in wheelbase was made possible by a completely new transaxle design that had been in the works since the winter of 1934 / '35.

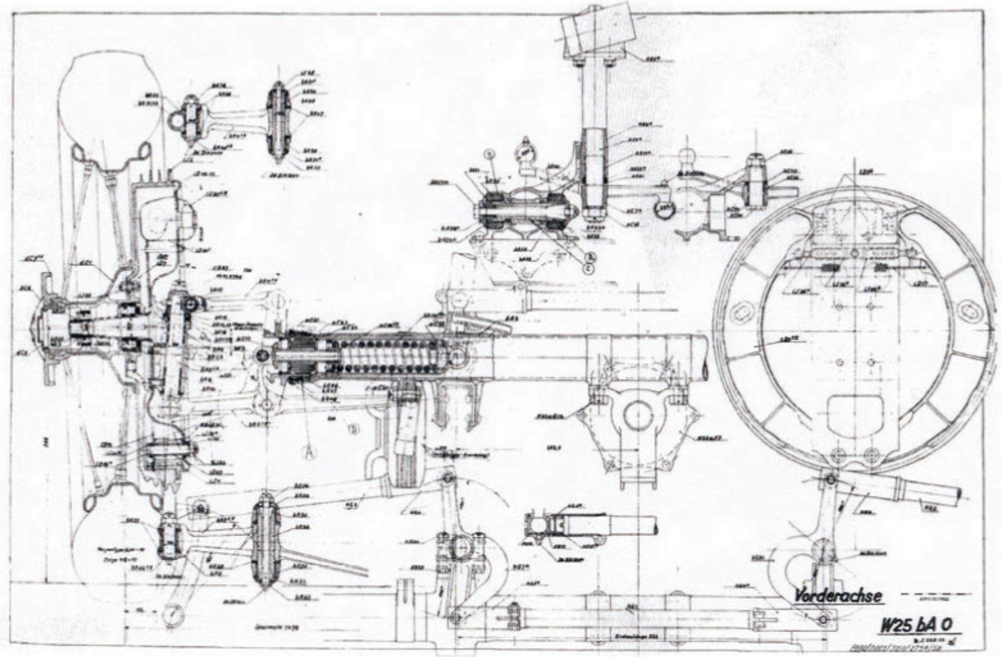
The new transaxle further lowered the car's propshaft by placing the two gearbox shafts in a transverse plane below the final drive gears, a radical departure from the normal longitudinal shaft axis. Stacking these shafts one above the other and laterally beneath the differential cleared – for a lower-seated driver – the space ahead of the rear axle that the transmission formerly occupied.

The drive from the propshaft entered the gearbox at the centre of its bottom shaft through a pair of bevel gears that could be varied one tooth or so either side of a 1:1 ratio. Four speeds and reverse were spaced along the two transmission shafts, to the left and right of the central bevel, still selected by sliding the gears into engagement with each other.

At the centre of the upper shaft, a pair of spur gears took the drive to the differential. These gears provided the normal ratio reduction, for example 3.69:1. On the W25K, the differential choice was between a fully locked rear end, with no differential action at all, and the ZF self-locking, cam-action diff'.

'Box of trouble

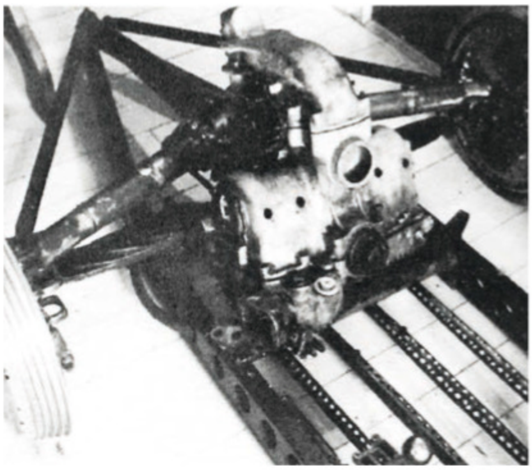
First runs in the chassis took place in the late summer of 1935 in a W25-based mule at the Nürburgring and Bern circuits. They showed the transaxle had a tendency to become too warm, so attention was given both to its cooling, by means of ducting, and to its oil capacity, which initially was slightly more than half that of the 1935 transaxle. Monza trials also showed the need for a re-design, giving higher torque capacity throughout the gearbox.



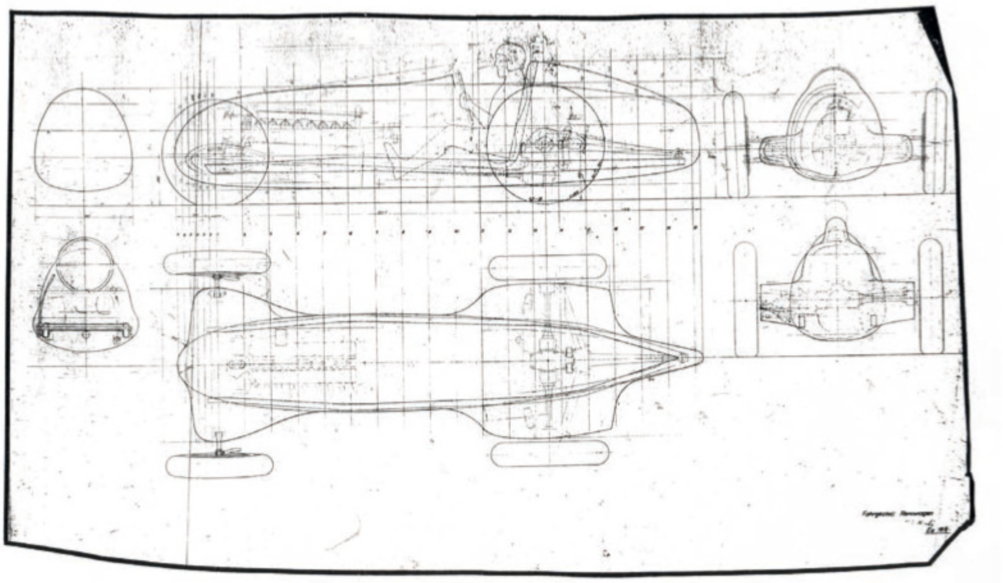
The 1934 front suspension design, with short parallel arms, was carried over to the W25K. A bell crank from the lower arm operated a coil spring inside a transverse structural tube. The short, close arms gave neither enough travel nor enough stiffness in the new car

By late 1935, the W25 was finding it increasingly difficult to apply its increasing horsepower to the ground, and the added power aggravated another attribute of the earlier car. If the rear end broke away in a corner, it was very difficult to catch. Consequently, as well as the shorter wheelbase, the W25K had an entirely new rear suspension. Gone were the swing axles – judged at least partially at fault – and the heavy pivots to attach them to the sides of the differential, replaced with a design that worked well enough before: a solid axle.

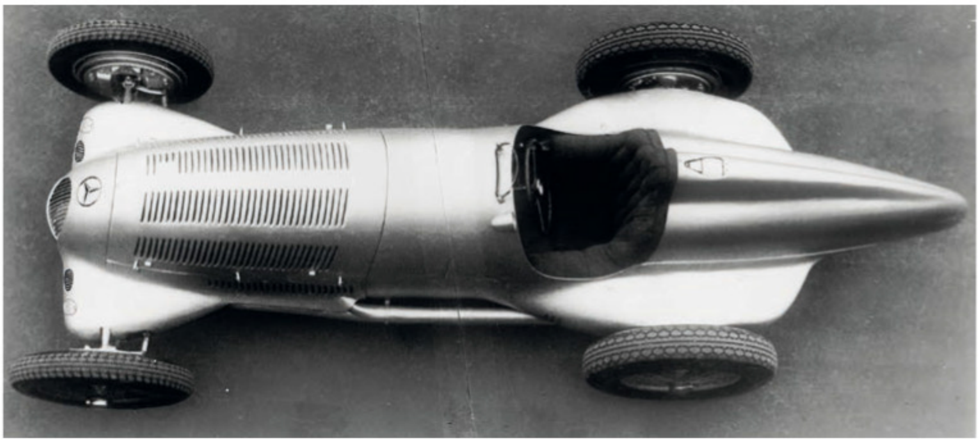
It was a solid axle with a difference though. To the Daimler and Benz engineers, their roots deep in the origins of motoring, it was an axle like those used on the company's earlier grand prix cars, like the Blitzen Benz.



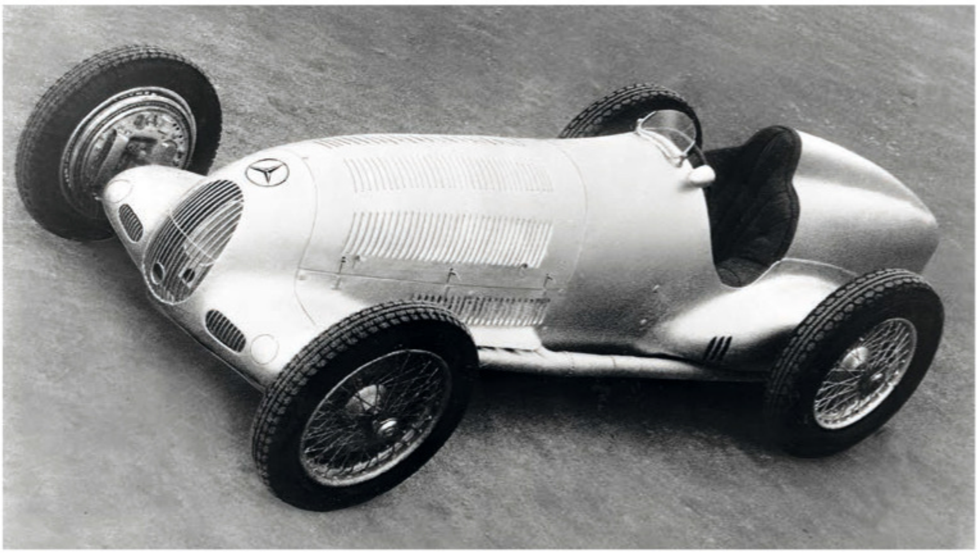
This W25K chassis shows the new transaxle and Wagner rear suspension, the latter having the struts that were added to brace the axle from the pivot to the rear hubs when that proved a weak point



Thanks to the new chassis layout, designer, Josef Müller, was able to draw a sleek, low-drag body, enclosing front and rear suspensions

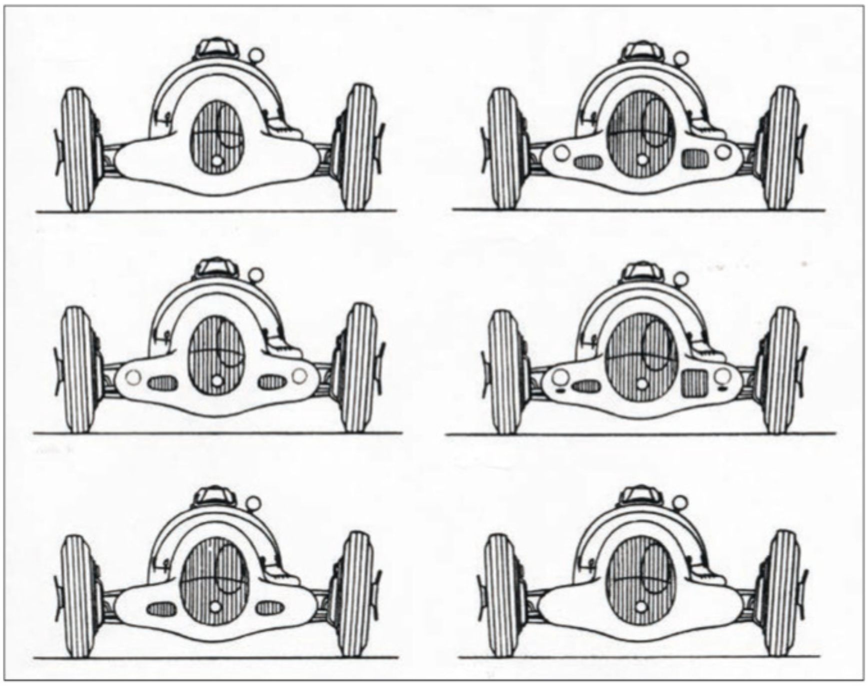


The smooth fairings of the W25K were an entirely new look for a racecar in 1935. Wind tunnel testing contributed to its svelte lines



Replacing the high exhaust of the W25 with low piping, running under the suspension, was also a new look for contemporary racers

[The rear suspension] was an independent re-invention of what a later generation would come to call de Dion rear suspension



Although the 1936 career of the W25K was truncated, its designers had time to try a number of different front-end configurations, as shown by these Louis Sugahara illustrations

It was a dead axle, joining together wheels which were driven not by chains, this time, but by open shafts, each with two universal joints. It was an independent re-invention of what a later generation would come to call de Dion rear suspension after the French producer that used it in production models in the early years of the century.

The axle was made of steel tubing in the shape of a broad-topped Y. The upper arms of the Y reached out, in plan view, to the wheel hubs, while the tail extended rearward to a ball pivot anchored to the rear end of the frame. The latter tapered inward to a point at that junction. This pivot was a critically important location point, taking both braking torque and transmission drive thrust.

This unique de Dion configuration was adopted, said Rudolf Uhlenhaut later, because 'Mr. Wagner wanted a good looking car.' This was achieved so well that the dead axle was completely concealed. Indeed, many observers still believe Mercedes-Benz adopted the de Dion axle for racing in 1937 rather than 1936, as it only became visible, in a new configuration, the following year.

Roller derby

An additional means of guiding the solid axle was needed to cope with the lateral forces experienced in cornering. This was supplied by a vertical fin fixed to the back of the transaxle casing. Within the crotch of the axle Y, riding up and down the sides of this fin, were two rubber-faced rollers attached to the axle tube.

Under the supervision of Dr Maruhn, a theoretician who ran a general research department at Untertürkheim, a rig was built to test the rollers for durability. Under moderate load, the first one lasted just 12 minutes.

During tests of the first car at Monza in December, the rollers continued to be troublesome, leading to suggestions for armouring the rubber, enlarging the rollers and isolating the guide fin from the heat of the differential.

During the 1936 season, the rollers were abandoned in favour of a steel-sided slot in the back of the transaxle, in which slid a bronze block attached to the crotch of the axle Y by a projecting ball pivot. This would set a style for de Dion lateral guidance that would last well into the 1950s.

When bracing by the tail of the de Dion proved inadequate, struts were added between its pivot and the hubs. Thanks to the car's all-enclosing bodywork, this later bodge was invisible.

Quarter-elliptic leaf springs with friction shock absorbers were retained at the rear of the chassis. The latter was founded on an extensively lightened, box-section frame similar to that of the 1935 model.

The front suspension was carried over almost unchanged from the previous car, within its tubular crossmember.

Thanks to all the changes, especially the new transmission design, the car's c of g was lowered by a remarkable 15cm (5.9in).

Brakes, to which screened cooling air inlets and outlets were added during 1935, were also transferred to the W25K. For better cooling, the rear vents were fitted with a coarser mesh screen, while the drums were given finer fins. Each brake was equipped with two grades of lurid lining corresponding to the different workloads of the two shoes.

Body beautiful

Designed by Josef Müller, the new body wrapped around the radically lowered car with an almost circular cross section. A long, slim tail and deep fairings concealed the front suspension and the adventurous new rear suspension. It was one of the handsomest racecars ever built.

When the cars first appeared for a presentation at the Berlin Auto Show in February 1936, they had a single oval radiator air entry. After testing, this was supplemented by two additional grilles in the front fairings.

The left-hand grille was enlarged early in 1936 to accommodate an oil cooler, a first for a Mercedes-Benz GP car. It was judged so successful that oil coolers were also added to the 1935 cars that were being carried over to the new season.

Exhaust piping was newly positioned down at ground level, sweeping back on the left below the rear axle.

One reason the 1935 W25s were still on hand at this point, apart from their value as training and back-up cars, was that the cockpit of the shortened Model 1936 was so tight that Manfred von Brauchitsch couldn't drive it comfortably.

'In a car calculated down to the gram,' said Alfred Neubauer, 'additional reserves for an extra-large driver are naturally impossible.'

Offered one of the older cars for the season, von Brauchitsch instead contrived to squeeze himself into the new one, except in the Eifelrennen, in which he drove a modified 1935 car.

After the first trials, one W25K went to the Zeppelin wind tunnel at Friedrichshafen for an aerodynamic evaluation, and changes were made to the body to give the drivers more protection from the wind.

Monza tests showed the need for an enlargement of both the main grille opening and the radiator itself.

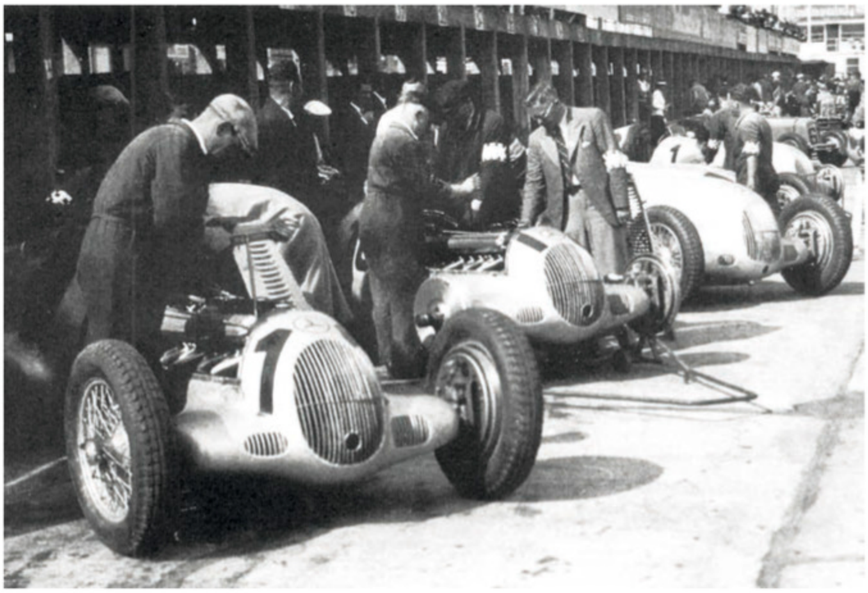
Test figures

All these early tests were carried out with M25C engines. In late February, the first ME25 went on one of Georg Scheerer's two dynamometers for a

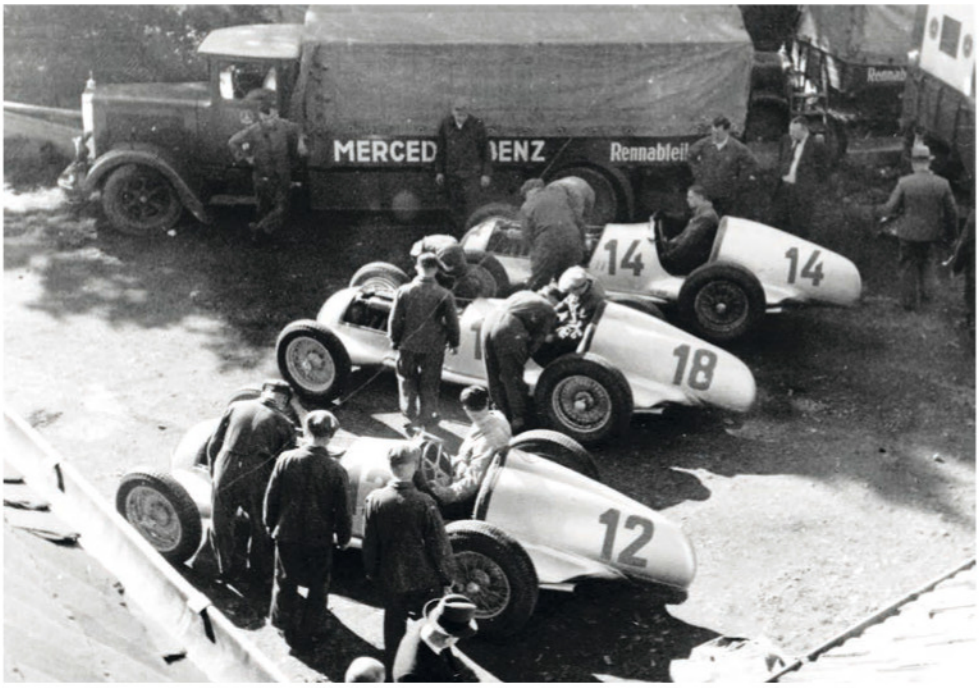
Thanks to all the changes, especially the new transmission design, the car's c of g was lowered by a remarkable 15cm (5.9in)

The two new W25K Mercedes bracketed the Scuderia Ferrari Alfa Romeo of Nuvolari at Monaco on 13 April 1936. The cars were sensationally lower and sleeker than the Italian racer, but promised more than they delivered

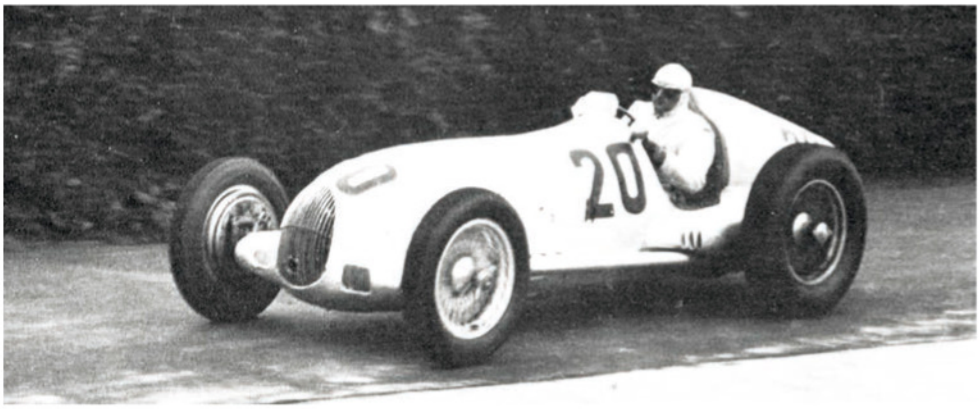
Although chased along the drenched Monaco track by two Auto Unions, Caracciola held the lead to win at an average speed of 51.7mph, the slowest winner since 1930. This marked one of only two victories for Mercedes' new racecar



During practice for the 1936 Eifelrennen, all four new W25K models were in the pits. Of the two entered in the event, only Chiron's survived the duration of the race, and came home in a lowly sixth place



The 312-mile German Grand Prix of 1936 was crunch time for the W25K, now equipped with its bigger engine, sporting completely new cylinders and blocks and the longer 255mm blowers. Car no.12 was for Caracciola, 14 for von Brauchitsch and 18 for Chiron



Rear tyre sizes increased greatly during the W25K's brief career. Running second in the early laps at the German GP, Lang's car was given to Caracciola when he retired after a crash. The best position for a W25K was fifth behind three Auto Unions and an Alfa Romeo

The shorter chassis of the W25K had a tendency toward pitching, which made handling unpredictable. This, combined with the unreliability of some engine components when pushed to the limit, as required to keep up with its rivals, led to numerous failures

With a compression ratio of 8.65:1 and the 255mm long supercharger, the ME25 [engine] gave its best ever power reading of 473bhp at 5800rpm

durability test. Its uncorrected output was 430bhp on the normal fuel blend, equal to 449bhp at 5000rpm with the standard corrections applied.

With a compression ratio of 8.65:1 and the 255mm long supercharger, the ME25 gave its best ever power reading of 473bhp at 5800rpm, recorded during the summer of 1936. Its typical output as prepared for racing with the 240mm blower and a compression ratio of 8.17:1 was 453bhp at 5800rpm, with a maximum torque of 465ft.lbs achieved at 3000rpm on a boost pressure of 14.5psi, exactly 1bar.

Output was excellent from an engine that was even lighter than the M25C at 465lb (211kg). For the first time, a Mercedes-Benz racing engine produced more than one horsepower per pound.

Racing record

To spectators at Monte Carlo on 13 April for the first grand prix of 1936, nothing appeared to have changed, except the smooth shape of the silver cars on the front row of the grid. Caracciola tiptoed through a rainy race to win after most of his team mates were sidelined by crashes at the chicane.

Not until they arrived at the fast, hot Tripoli circuit in May did the drivers have a chance to fully extend the W25K with its new ME25 engine. Comparing it with the same engine in the 1935 chassis and body, albeit with slightly different gear ratios, both recorded the same 175mph maximum speed.

Caracciola complained of understeer, which was reduced by replacing the locked differential with a ZF unit. Even then, the drivers were generally dissatisfied with both the roadholding and steering, which still mustered a strong steering wheel kick back.

Technically, the Tripoli race was as inconclusive as Monaco. One of the 255mm blowers failed in practice so all the cars were switched to the 240mm unit for the race. One car, that of new man Louis Chiron (a Monegasque, and close friend of Caracciola) suffered minor troubles that retired it.

The uncomfortable von Brauchitsch stopped on the circuit when his tank failed to feed all its fuel, a problem noted in the Monza trials but not rectified, while both Fagioli and Caracciola lost their front brakes after a pipe failure caused by the new mounting of the front-circuit master cylinder on the right rear engine bearer.

The drivers all found their cars very sensitive to the windy conditions on race day, observer, Jakob Krauss, noting they looked less steady on the turns than the Auto Unions.

'Perhaps,' mused Neubauer afterward, 'the longer chassis is better for fast courses.' That axiom had many echoes.

A further victory was achieved in another race in North Africa, at Tunis, when the leading Auto Unions crashed and burned, but it was the last win to fall to Rudy Caracciola and the Mercedes-Benz W25K.

At Barcelona, Nuvolari's Alfa beat the new cars in a straight fight. Here the sharp pitching tendency of the shorter chassis was especially bothersome. Pitching was also a problem at the subsequent Eifelrennen that saw all but two of the cars retiring, and those that finished well back in the order. Engine trouble struck there, and in the subsequent race at Budapest, where all the Mercedes-Benz machines failed.

The new engine, pushed hard at last, had shown a critical frailty. Cylinders in the forward block were too weak to handle the high specific output and had begun to fail. Initially, the existing parts were strengthened, but then completely new cylinders and blocks were made for the all-important German Grand Prix in late July. Before that race, several of the engines were switched from 240mm to 255mm superchargers, two of which subsequently broke. In the race, Chiron crashed and one car limped home sixth.

After such a run of disasters, any sporting team determined to be victorious would call a rapid halt and make some changes. So too it was with Daimler-Benz. The organisation that had served it so well since automobile racing began was apparently no longer equal to the pace and intensity of grand prix racing in the late 1930s.

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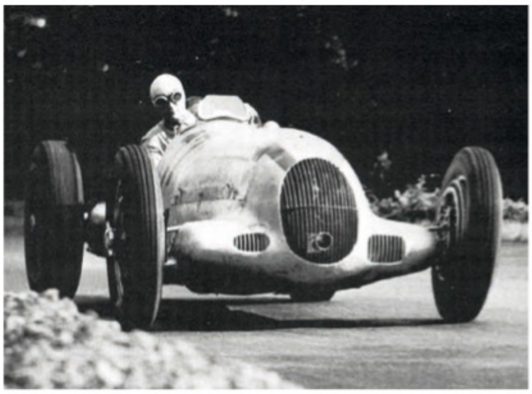
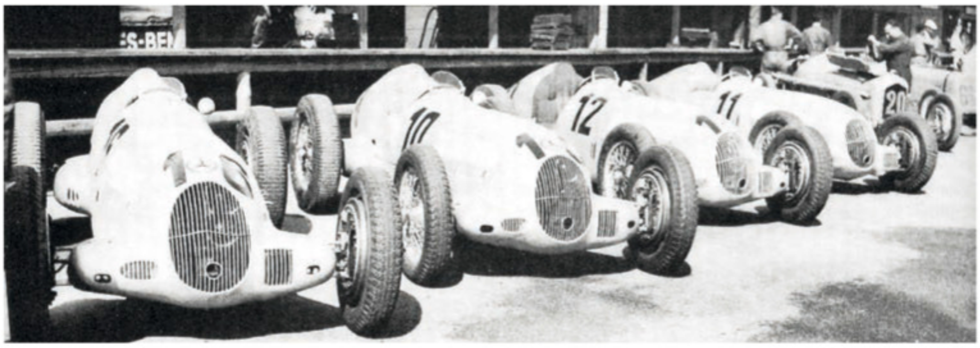

Another view of Chiron on the Nürburgring shows the increased size of the grille delivering air to the newly fitted oil cooler. The car's front suspension, designed in 1933, was no longer up to the job



After major changes under Rudy Uhlenhaut's new Racing Department, four W25Ks mustered for the Swiss Grand Prix on 23 August. Mighty efforts won pole for Caracciola and Mercedes, but the best result in the race was fourth for newcomer, Hermann Lang

Racing Department

The liaison between Alfred Neubauer's Sports Department and the engineers in the central design office had always been direct. This changed with the creation of a new technical body specifically concerned with the company's racecars. An offshoot of the Experimental Department, it was called the *Rennabteilung*, the Racing Department.

Placed in charge of it was a handsome young man who had been with the company only five years. Born of a German father and British mother, he had joined Daimler-Benz directly from engineering school as a carburetion specialist in the Experimental Department. The arrival on the scene of Rudolf Uhlenhaut marked a turning point in the racing history of Daimler-Benz.

Uhlenhaut's new group was made fully responsible for assembling, preparing and testing the cars, then turning them over to Neubauer's Sports Department for racing. Reporting directly to Fritz Nallinger, who headed the main Experimental Department, Uhlenhaut was assigned the services of Jakob Krauss in charge of car construction and Georg Scheerer as head of testing and inspection.

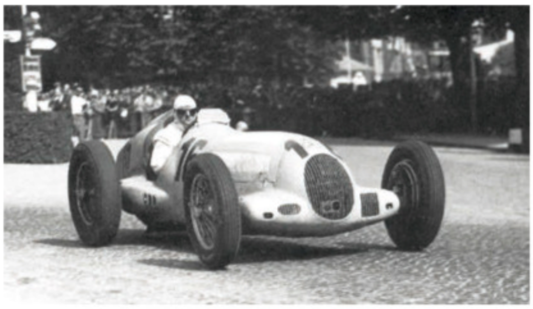
'Naturally, we had a good design office,' Uhlenhaut said, 'but the people there were cautious, and our opinions often differed. However, if I wanted something, I said so and they would generally let me have it.'

He and his colleagues said what they wanted in their recommendations, expressed from mid-1936 onward in a blizzard of reports, memos and analyses generated by the new *Rennabteilung*.

It was too late to do much about the W25K, which Uhlenhaut tested extensively at the Nürburgring. Race entries at Montenero and Pescara were abandoned in order to try and ready the cars for the Swiss Grand Prix on 23 August. There, Caracciola took and held the lead, until Rosemeyer motored past him, and the right side of his rear axle tube broke. Fagioli, meanwhile, broke a connecting rod and von Brauchitsch had cooling failure initiated by a piece of newspaper caught in front of the grille. Newcomer, Hermann Lang, eked out a finish in fourth place.

'The drivers declared themselves as by and large satisfied with the roadholding, with empty as well as with full tanks,' Uhlenhaut recorded. 'In this race, it was clearly evident that the power of the Auto Union in the middle and upper speed ranges is far superior. To be able to hold the pace to some extent, our drivers must constantly strain the engine to the limit and, moreover, attempt to gain back in the turns what they lose on the straights.

'A further participation in racing with the E motor seems to be useless,' Uhlenhaut concluded.


Racing on the fast, demanding Bern circuit showed Lang's merits as a driver. He held second and third before withdrawing with a hand injury

In March 1937, two of the ill-fated W25K models joined the new W125 at Monza for the drivers to get up to speed. New hire, Dick Seaman, took advantage, but later crashed

Daimler-Benz management agreed with him. Entries for the Italian Grand Prix, the European season's final event, were withdrawn. It was a heavy decision for the proud company, but the light shone on the technology of racing by Uhlenhaut's new group would bring brilliant results in coming years.

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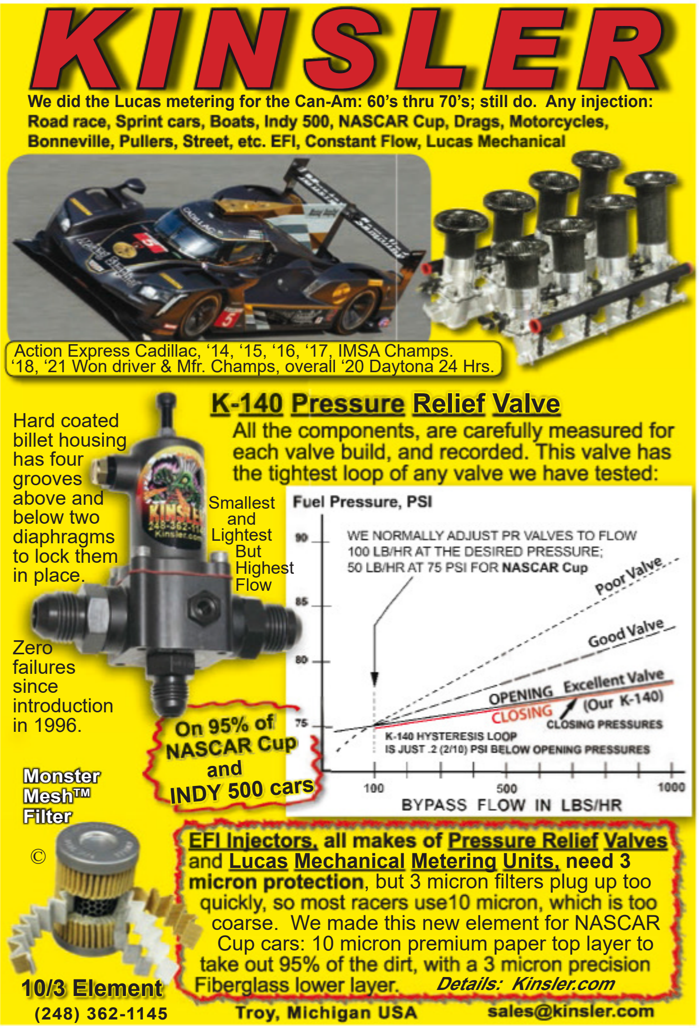

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Small, but perfectly formed

Tracing the development and evolution of the Global MX-5 Cup racer

By TOMMY PARRY

Regular IMSA race fans will be familiar with the diminutive Global MX-5 Cup car, and the consistent entertainment it has provided for the better part of the last decade.

While the Mazda MX-5 has always been synonymous with simplicity, developing the racing version of the fourth-generation MX-5 (chassis code ND) was an exacting engineering feat for four companies with an interesting set of compromises to consider. The four were tasked with building an exciting, competitive, professional-level racecar that had to be approachable for racers of all abilities, cost effective and extremely reliable.

From the start, Mazda wanted a homologated car capable of running in multiple different professional and club categories around the world. This globally recognisable platform had to be synonymous with parity and accessibility.

Since Mazda wanted the Global MX-5 Cup drivers to primarily focus on car control and racecraft, it had to be relatively simple to operate and very robust. This car was not intended to help exercise engineering creativity, nor to require serious maintenance throughout a season. Ease of operation was emphasised, and it had to remain tuneable enough to accommodate a wide range of drivers. It's a big ask to build a car sharp and competitive enough to fit

Mazda

One of the racecars having its suspension aligned prior to customer delivery. Cars are supplied with a basic, workable set-up, with scope for the customer to fine tune to suit their requirements

The four [companies] were tasked with building an exciting, competitive, professional-level racecar that had to be approachable for racers of all abilities, cost effective and extremely reliable

Mazda

The FIA-certified rollcage design was arrived at through extensive torsional testing of the chassis. By being slightly proud of the roofline, it has enabled bumper-to-bumper drafting

within the professional sportscar ranks, but still be approachable enough for the amateur club racer to enjoy.

It therefore had to have enough adjustment to optimise for stickier tyres over a qualifying session on a bumpy circuit, but not so much as to mire the less experienced customer in set-up challenges.

With the basic objectives laid out, Mazda needed to find some gifted partners.

Close control

Ensuring the playing field was as even as possible was no mean feat. It was decided that the engines, gearboxes, differentials, ECUs and dampers would all be sealed. 'Our customers had to trust the seal,' says Glenn Long of Long Road Racing, technical partner selected to spearhead development.

Along with the hardware above, organisers also standardised the engine oil. 'We didn't want any customers with an experimentational bent to start testing oils on the engine dyno,' Long adds.

Then there was the control from the organisational standpoint. Stringent drag measurements on the drivetrain keep the cars close in performance. As the engine has relatively little power, any minor variance in drivetrain drag would make a major difference. Fortunately, chassis dyno testing revealed all frictional losses were within a window of one to two per cent.

Mazda also supplied the fuse and power. After re-locating the battery to the rear of the car, the manufacturer added five power ports on the battery box. This allows drivers to power their cameras and cool suits, and also helps policing. This is tested through resistance readings taken at the front and rear of the car during tech. Additional wiring would add noticeable impedance.

Blank slate

Without any real racing history, the ND platform could be optimised within the aforementioned constraints. That began with Long Road Racing receiving a stack of CAD drawings and three base cars. Soon after, they put chassis no.11 on a kinematic and compliance (K&C) machine.

By subjecting the chassis to vertical and lateral loading at low frequencies, alignment and roll centre changes throughout the full range of suspension travel could be studied.

This allows the engineer to ask the following questions:

- When the suspension arms, uprights, wheel, joints and brackets are loaded, where are the wheels pointed?
- What is the measured-as-installed rate of the anti-roll bars at the wheel?
- What is the tyre spring rate and how does it change with tyre pressure?
- Where are the force-based roll centres and how do they move under realistic cornering loads?
- Is there an issue with a part of the suspension, or a bracket bending?
- What is the anti-dive, anti-squat and anti-lift of the loaded car?
- What is the steering geometry?

- How much friction is there in the suspension, and does it bind under load?
- What is the real motion ratio, and how does it change with rocker position or wheel travel?

Through this process, the engineers at Long Road learned that Mazda had done great work. Unlike the third generation (NC chassis) cars, the ND had none of the unfortunate rear toe-out gain under compression. The added rear stability would aid in putting down more power, but that would also require a stiff chassis.

After that, they began assessing the stiffness of the chassis by subjecting the car to torsion, axial and longitudinal folding.

Obtaining a greater sense of how and where the chassis flexed informed the rollcage design. It was decided to use eight connection points – the maximum number allowed by the SCCA and NASA rulebooks with which, along with the FIA's rulebook, the 'cage had to comply.

The structure also had to be symmetrical as the car was intended for both left and right-hand drive models, though all the cars eventually raced were LHD.

'The symmetry turned out to be a feature, not a bug,' notes Long. 'We could safely include a passenger with the same protection as the driver, which appealed to the weekend warrior.'

In the end, the 'cage design Long Road Racing decided upon was modelled closely on an FIA rally-spec 'cage. Though heavier than desired, the cage weight was offset by the 2100lb (953kg) car being underweight.

IMSA then presented the prospective 'cage design to the FIA. Following its certification, Long Road Racing TIG welded a physical structure into chassis no.11, which then made a return to the K&C machine for another round of measuring. This time, the engineers wanted to understand the effects of the 'cage on the car's chassis.

'The 'cage met all of our goals for rigidity and safety without negatively affecting suspension movements,' Long reports.

To progress further, though, they needed another machine.

Shake it all over

Long Road Racing needed to add more detail to the cloudy picture provided by database results, driver feedback and trackside observations. For this, they needed to use a shaker rig.

'The K&C rig moves at a much slower rate, but it takes lateral and vertical loads into account. In contrast, the shaker rig analyses mostly vertical loads, but it can do it at much higher speeds and replicate events you would experience out on track, like kerb strike,' explains Aaron Lambert, general manager at Penske Racing Shocks.

Essentially, it allows engineers to trust their data, and make specific rig changes without using tyres and fuel.

The basic shaker test puts the car through a sine sweep to understand the chassis' harmonics. At a certain vibration, the suspension will stop reacting quickly enough and begin to transfer the load to the tyre.

For more detail, they can use the shaker for 'track replay'. This begins with the engineers outfitting the suspension with instruments to take data at a track session.

Whatever is gleaned from that track session is then compared to what the shaker told them in the sine sweep. If the shaker rig's simulation model is corroborated by

> **'The K&C rig moves at a much slower rate, but it takes lateral and vertical loads into account. In contrast, the shaker rig analyses mostly vertical loads, but it can do it at much higher speeds'**
>
> *Aaron Lambert, general manager at Penske Racing Shocks*

Mazda

NC
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As the previous ND chassis was, the latest racing variant of the NC was tested on a K&C machine, and then optimised on the shaker rig, which can replicate events a car would experience on track

Drafting at 150mph on the Daytona banking in a tiny, open-top sports car has been described by drivers as a surreal experience, and makes Global MX-5 Cup a crowd favourite wherever it appears

on-track testing, the data can be trusted, and on-track behaviour can be studied in greater detail in the comfort of their own facility. Predictably, track replay helps control for variables like driver subjectivity and atmospheric variations.

In this instance, Long Road Racing didn't need to take the second step. Designing the racecar from zero allowed them to nip many potential issues in the bud through the extensive K&C testing process, so the shaker was used mainly to study harmonics and diagnose any clearance issues with the suspension components.

Damper testing

With the chassis largely sorted, Mazda began the search for a damper that would provide the predictable, consistent, understandable adjustments the manufacturer was seeking.

The list of adjustments was short: toe; castor; camber; ride height; damper setting and tyre pressure. After putting out requests to several major manufacturers for a damper that suited the chassis and the tyre specs, testing began. Long Road Racing undertook a group evaluation by first putting the supplied dampers on a shock dyno, and then giving them to Tom Long and Andrew Carbonell, two of Mazda's most experienced sportscar drivers, to test on two mules at Carolina Motorsports Park.

Multimatic's DSSV damper had a couple of distinguishing traits, one being the linear distribution of its force.

'This made setting up an intuitive process, one that everybody had a similar chance of understanding,' says Long. 'The damping rate was consistent, from the first to the last click of adjustment. We wanted to keep our customers from having to dyno the damper to find its sweet spot.'

Also, the absence of an external reservoir would spare the drivers a potentially complicating variable of canister pressure. Again, simplifying the set-up options was in keeping with the spirit of the series, and so Multimatic was brought onboard.

'Multimatic found a spring rate that worked with its damping solution. It was soft enough to absorb Sebring's bumps yet provide enough body control to handle the transitions on VIR's [Virginia International Raceway] smooth surface,' Long continues.

To find the right rubber, SOVA Motion joined the team and provided access to its three-storey tall tyre testing facility. Built like a giant belt sander that replicates a road surface, it allowed Long Road Racing to test the tyres for slip angle, grip and durability before on-track testing.

Eighteen different tyre manufacturers provided models for analysis, and the information gleaned through those tests pointed Long Road Racing in the direction of BF Goodrich, whose tyres rated best at the subsequent real-life test.

If the BF Goodrich tyre's performance piqued the team's curiosity, it was the company's willingness to tailor a tyre to the car that clinched the deal.

Real world testing

With all three parties exchanging information freely, Multimatic and BF Goodrich were able to begin building prototypes with guesses as to where the dampers and anti-roll bars ought to be set.

Once the mule car was equipped with prototype dampers and tyres, Long and Carbonell returned to undertake some real-world testing at a dozen different circuits.

Simplifying the set-up options was in keeping with the spirit of the series, and so [the] Multimatic [damper] was brought onboard

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MAZDA
MX-5 CUP
BFGoodrich
54
idemitsu

Mazda

The uprated 2023 brake package from Brembo improved thermal capacity without shortening braking distances and reducing the chances of passing. Spec tyres are supplied by BF Goodrich

'We only tested one variable at a time,' says Long. 'We tested for performance in thin air, its performance at high speeds, under high braking loads, and even on an oval under maximum lateral loading. We needed to know if the car would bottom out at a track like Daytona.

'We had to understand how the [tyre] pressures and temperatures changed dynamically, so we instrumented basically every suspension component. We used infrared sensors to study the tyres mid-corner, as well as transponders within the wheel to measure air pressure changes in long, sweeping corners.'

The addition of Setrab coolers resolved the gearbox and differential's heat concerns, and adding an upgraded C&R radiator kept the engine suitably cool. However, excessive brake temperatures required a more elaborate solution.

The issue was with construction of the stock Brembo disc. Instead of being joined by vanes, the flat-faced rotor was joined by slugs, which did not flow enough air. Brembo consequently added cooling grooves on the disc surfaces to bring temperatures down to a reasonable level.

Though the factory Brembo four-pot calipers weren't tested against other brake packages, Mazda wanted to ensure the braking system was optimised in its pad and fluid selection. The potential pads were evaluated first on initial bite, modulation and release, and then on consistency and lifespan. Once Pagid pads were settled on, along with Brown & Miller Racing Solutions lines and Castrol SRF fluid, the braking system could handle all the abuse happily. Indeed, aided by the stellar factory ABS, the braking package became one of the Global MX-5 Cup cars' strong points.

The car had to be more than just well set up, and capable of keeping cool, though. To obtain the public's approval, Long and Carbonell toured the country with two cars. Spending their time at country club-style circuits like Autobahn and Monticello, they offered selected club racers the opportunity to give their impressions of the car.

Public approval

'Initially, some found the car a little soft, but we'd done this intentionally as this was how the car was fastest in most hands,' Long remembers. Most of the criticisms from the more discerning drivers were quelled with a front anti-roll bar adjustment, or more rebound at the rear. Everyone else simply remarked on how much fun they had driving the car.

The announcements, and subsequent online reviews, generated such a buzz that in the week following the Global MX-5 Cup car's reveal, all 25 units were sold.

With just those minor modifications, the MX-5 ran strongly for three seasons. It wasn't until 2019, the MX-5 Cup's fourth year of competition, that the mid-generation update (ND2) arrived. At that time, Long Road Racing was downsizing, and so Flis Performance took over as technical partner.

The new company's first challenge was addressing the overheating problems suffered with the ND2's punchier motor.

'We found the air was stalling in front of the radiator, so we mounted a diffuser underneath the carpet tray to pull air from the backside of the radiator,' explains Troy Flis of Flis Performance.

Besides that, the only other items needed to keep the engine appropriately cool were some ducting, a raised radiator cap and a little tape to seal the radiator.

> **'We tested for performance in thin air, its performance at high speeds, under high braking loads, and even on an oval under maximum lateral loading'**
>
> *Glenn Long, owner of Long Road Racing*

The heat issues weren't totally over, though. More power kept the cars closer in the draft and, at places like Daytona, 30 seconds of drafting began melting the plastic front bumpers. To fix this, Flis Performance designed a turn-down exhaust that exited after the rear subframe.

Mazda wanted close competition, and that's what it got.

Crafty behaviour

After one year of running the ND2, as the talent of the drivers and their overall performance increased, the shortcomings in the factory gearbox became apparent. Some of the more crafty drivers found that just dipping the clutch and avoiding a clean, sympathetic shift could save them a few tenths, though not all the gearboxes handled such brutish behaviour.

Mazda leadership felt this inconsistency reduced parity, so it removed this variable by replacing the factory unit with a Sadev SCL82-17 six-speed sequential 'box.

'Besides needing a larger hose for cooling, the Sadev [gearbox] made the car more reliable,' Flis recalls.

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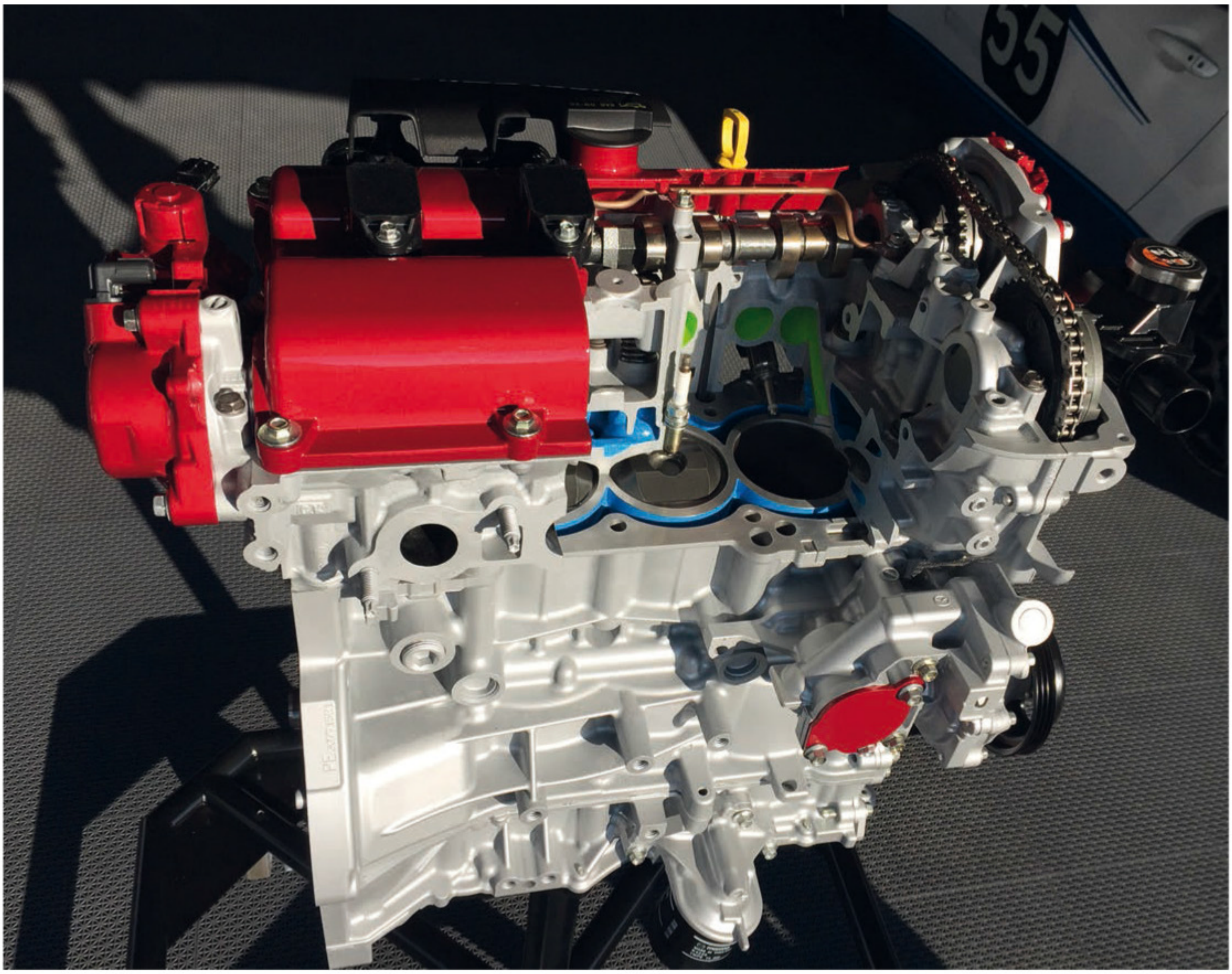

Mazda

Producing around 200bhp, the Skyactiv-G (PE-VPS) motor has proven a dependable workhorse. It is supplied as a sealed unit and many racers report no drop off in power after a season's racing

They were now able to run 150mph in the draft at Daytona, a boast few production-based cars with a mere 200bhp can make

It made the cars faster, too. Racers immediately saw a three-second drop in lap times at all North American circuits. Even more impressively, they were now able to run 150mph in the draft at Daytona, a boast few production-based cars with a mere 200bhp can make.

'Driving the MX-5 Cup on Daytona's banks was surreal,' remembers Sam Paley, 2021 Mazda MX-5 Cup Rookie of the Year. 'The wheel gets light and my helmet gets buffeted by all the wind; an exhilarating experience for any driver.'

Unfortunately, such excitement came at a price. It wasn't just higher top speeds overheating the front brakes. The sequential gearbox's taller ratios, no longer exerting the same load on the gear and pinion, took parasitic friction at the rear brakes out of the deceleration equation and compounded the problem at the front.

While the brakes' thermal capacity had to be increased, the braking distances couldn't shorten, since regular overtaking was an integral part of the series' appeal. Brembo responded with a clever solution.

For the 2023 season, the cars have been fitted with a stiffer machined caliper with larger pistons. This, along with a thicker, floating, vaned disc with an aluminium hat, means drivers no longer deal with brake fade or pad knockback. Though this new package was not cheap, its reduced pad consumption should bring the cost to a break-even point.

A decade of thrills

As years of testing and racing proved, achieving true parity and approachability does not come easily, or cheaply. The original price of $53,000 (approx. £43,600) has grown, thanks largely to the introduction of the Sadev gearbox and uprated brakes, to a starting price of $81,000 (approx. £66,700). Fortunately, the running costs have not changed much. These racecars are regularly run for more than one season without any reduction in power.

At that price, the series might not be considered budget racing by some, but the Mazda MX-5 Cup, as it's now known, does still hold an interesting value proposition.

In addition to being the least expensive series currently in IMSA, the numerous payouts have given some drivers a chance to make a respectable living from competing. That certainly sweetens the pot.

As testament to their sound build ethos, and a willingness to listen to their customers' needs, Mazda sold all 275 of the cars it built. Nearly 60 per cent of them have found homes at racing country clubs, while many of the others share the stage with the IMSA WeatherTech Sportscar Championship, where, on occasion, they provide even better entertainment than the bigger, more powerful cars on the entry list.

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'The driver doesn't really care about the MGU-K, H or anything else, they just want to go fast or slow, save energy or use energy,' says McDonald-Walker. The real work on the energy management side is up to the engineers running the cars

Any energy management strategy must take into account not just the technical limits of how much energy you have to use, but also those imposed by the sporting regulations of a given series

Expectation management

Being competitive in 21st century motorsport hinges on understanding energy flows within a racecar. Racecar *talks to acknowledged expert in the field, Ruaraidh McDonald-Walker*

By LAWRENCE BUTCHER

Racing has always been about energy management, but in recent years it has become a sporting focal point of many series, not to mention a useful marketing hook in these environmentally conscious times. Whether it is Formula 1, Formula E or the WRC, understanding energy flows within a racecar are critical to success.

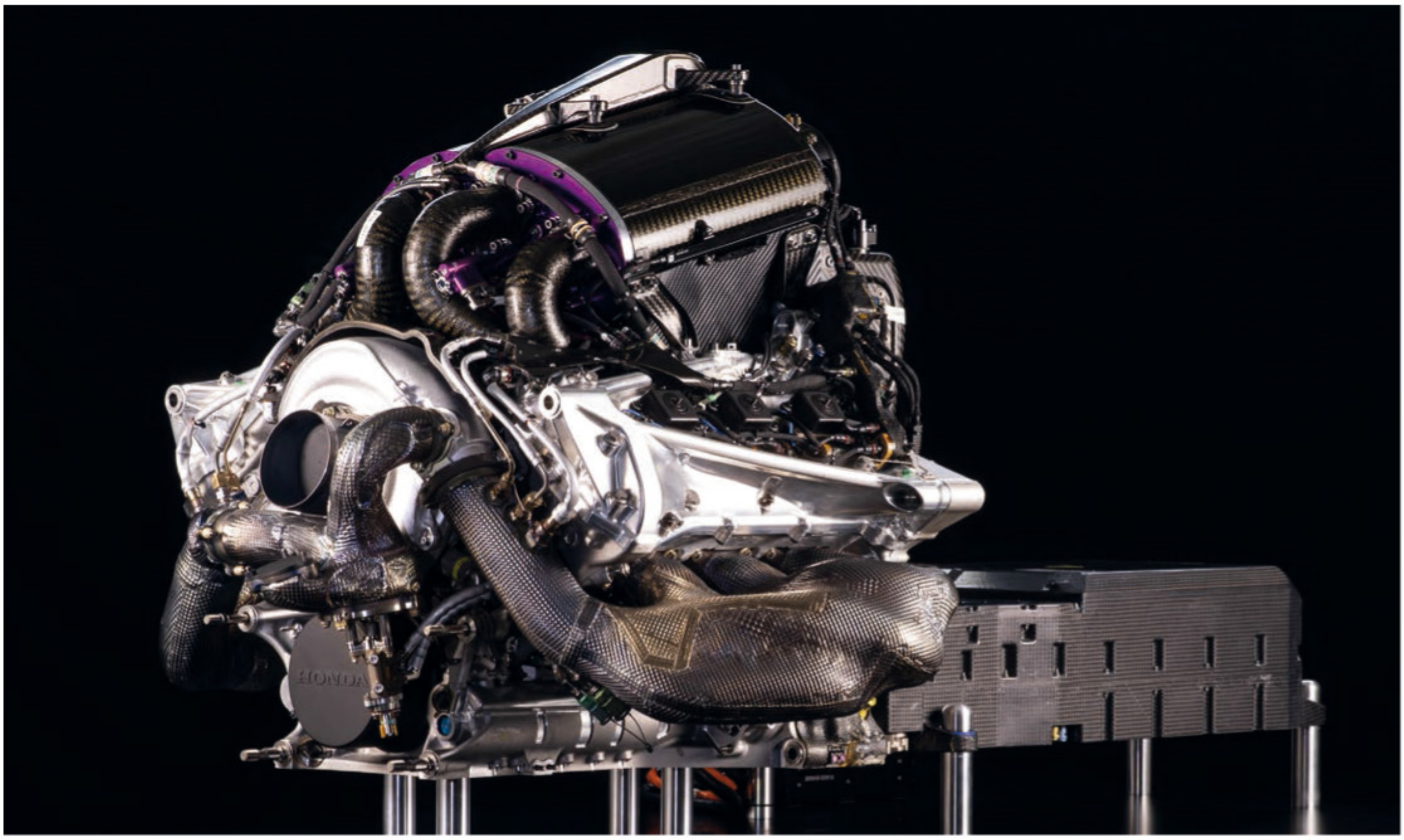
Ruaraidh McDonald-Walker's career has spanned the who's who of the cutting-edge powertrain development world, starting out at Cosworth before stints at Integral Powertrain (now Helix), then as development lead on KERS and ERS development at what is currently Mercedes AMG HPP, before joining McLaren as principal powertrain engineer. These days his role is technical director at McLaren Applied, the specialist electronics and software company that, until last year, was part of McLaren Group, but which has since been sold to Grey Bull Capital.

With experience across both Formula 1 and Formula E, as well as a host of other series, he is ideally placed to comment on how energy management dictates modern racecar performance.

Know your limits

Energy management in motorsport used to mean just one thing, fuel.

'If you go right back to the 1980s, with fuel injection and turbochargers, then it was as simple as consumption over distance,' says McDonald-Walker. 'You project a line, and does that line fall before or after the end of the race? Ideally, you want it to cough as it goes over the line.'



Current Formula 1 cars have extremely complex energy ecosystems, and successfully managing the delicate balance between the internal combustion engine and the ERS is critical to success

In series that retain traditional ICE power, this still rings true, except: 'Nowadays, we need to have things like fuel samples available at the end of the race, which shows the difference between a technical solution and a sporting limitation.'

This difference between a technical and sporting energy limit is, says McDonald-Walker, important. Any energy management strategy must take into account not just the technical limits of how much energy you have to use, but also those imposed by the sporting regulations of a given series, which can artificially alter the balance depending on competition conditions.

In the case of Formula E, this was starkly demonstrated in 2021 at the Valencia E-Prix, when even experienced teams were caught out by sporting limits. In the case of the then Gen-2 Formula E cars, though the battery capacity was technically 52kWh, this could be artificially limited depending on the number and duration of safety car periods.

'If there are lots of safety cars, then people save plenty of energy and it would turn into a sprint race, which the series doesn't want. So, they reduce the amount of sporting energy available,' he observes.

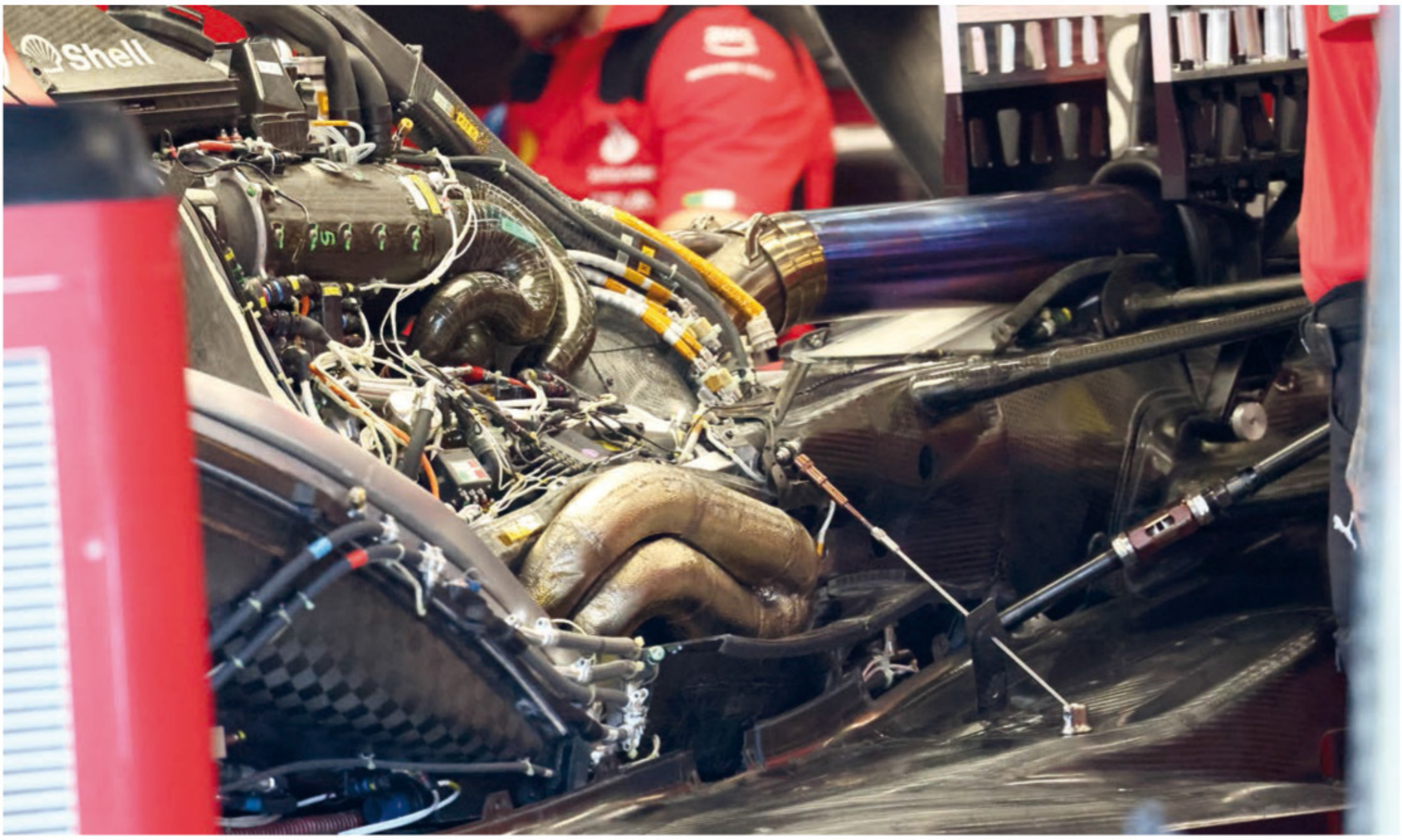
This is precisely what happened in Valencia, with somewhat farcical consequences. Only nine drivers were classified as finishers, with most of those slowing to a glacial pace, eking out their energy allowance just to cross the line. None of the cars' batteries were technically empty but, as far as the rules were concerned, they were after 1kWh of energy had been deducted for every minute spent under the safety car.

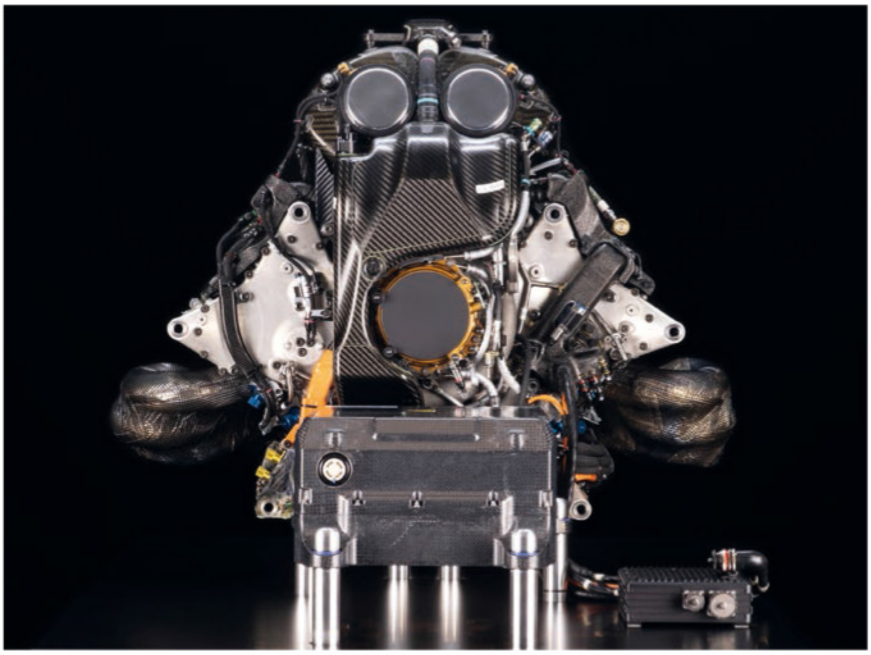
After nearly a decade of the current Formula 1 powertrain regulations, the energy flows are well understood

The hybrid challenge

Since the demise of the high-powered hybrid era in WEC, and the hobbling of current Hypercars by BoP, Formula 1 has the most complex energy ecosystem, with the balance between ICE and ERS inextricably linked. Again, there are technical and

[Energy] management can be broken down corner by corner, working through braking and corner entry through to exit and acceleration down a straight


That management of energy flows around a contemporary racecar is more complicated than just optimising for performance, it is now a vital tool for tactical and strategic decision making, too


Prior to the hybrid era, engineers just had to ensure the ICE was performant. Today, it's a complicated balancing act

sporting limitations on the way energy can be used. There is a 110kg maximum limit on fuel carried, and the fuel flow rate is capped at 100kg/hr. There are then various limitations on how energy is moved around the ERS system, for example, with caps on energy in and out of the battery each lap.

Ascertaining how best to manage these energy flows and use them both tactically and strategically through a race is vital to being competitive. McDonald-Walker explains how this management can be broken down corner by corner, working through braking and corner entry through to exit and acceleration down a straight. The intricacies of each team's approach vary, but the general principles are well established after nearly a decade of the current powertrain regulations.

'You need to analyse the entry, clipping point, acceleration point, and then down the straight. Breaking it down into the terms of how you can regenerate,' he outlines. 'Before the braking point, drivers will lift and coast, saving fuel, but they are regenning all the while. Then, as they brake, they are regenning more before getting into the corner entry phase.'

It is at this point a technique referred to as part-throttle harvesting can be employed. With the braking phase over and the engine at part throttle, it is possible to directly drive the MGU-K from the engine and charge the battery.

'You're modulating battery charge vs wheel torque vs throttle position, juggling rear tyre grip and front / rear balance,' highlights McDonald-Walker.

Role play

At the same time as the MGU-K is being used to feed the battery, the MGU-H also has a role to play. While the engine is at part throttle, the exhaust energy driving the turbine is low and, if left unassisted, the compressor speed would drop. Here, the MGU-H is used to keep it up to speed.

In order to reduce the energy required to achieve this, most power unit manufacturers deploy inlet guide vanes – normally used to optimise flow into the turbo under transient conditions – which can also be closed off.

'When they snap shut completely, the turbo is running in very rarefied air. So the amount of power you need on the MGU-H to keep it spinning at the 80-90,000rpm you want is very low,' explains McDonald-Walker.

The cumulative result is that energy regeneration takes place right through

RENAULT SPORT

On the MGU-H side, the turbocharger has become a tuning tool, F1 engineers working out how best to harness the inertia within the units to efficiently transfer energy flow between systems

the braking, turn in and apex sections of every corner. Then, as the driver starts to open out the corner and get on the power, that energy is put to use.

'You're then at a position where you're starting to ramp down the part-throttle harvest, and you start to move the throttle out. Then those guide vanes open and the turbocharger spins up,' says McDonald-Walker. 'Now the car is in the traction limited phase, you're still cornering but adding power. You can't add that much because your traction limited.'

Marginal sensitivity

Here's where the torque and power sensitivity of different sectors of a track need to be fully understood to make best use of the energy available. 'The energy that you put in at the very start of the straight has the biggest effect. You can put in lots of energy at the end of the straight, but it really doesn't have much effect on your lap time.

'As the car exits the traction limited phase and starts the acceleration phase towards eventual v-max, you have to look at the sensitivities of what would happen over a whole lap. What would the effect be if you just nudge the power up here or up there? Working out those marginal sensitivities all the way around the lap quickly shows you where you should best use energy for maximum effect.'

By now the turbo will be spinning at its maximum and the MGU-K will be feeding its full 120kW to the wheels.

'This means you actually have excess energy in the turbo, but the last thing you want to do is open the wastegate. The clue is in the name there. The boost would go through the roof with a closed wastegate, though, so what you do is brake the turbo shaft using the MGU-H and harness the considerable amount of energy available on the shaft.'

This means that even as the car is accelerating hard up the straight, there comes a point where energy can be harvested from the MGU-H and, as the

There comes a point where energy can be harvested from the MGU-H and, as the rules are written, this can be fed directly to the MGU-K

Turbo trickery

The F1 technical regulations have tightly policed limits on energy flows between the various components of the ERS. Notably, there is a limit on transfer of energy from the MGU-K to the battery of 2MJ per lap. However, there is no limit on energy transfer between the MGU-K and MGU-H, or from the MGU-H to the battery. There is potential on some tracks to harvest considerably more than 2MJ from the MGU-K, but how to get it to the battery? Enter some racing ingenuity.

McDonald-Walker explains: 'The turbocharger is a big old brute, typically with a 95-105mm compressor and a 85-95mm turbine. Add in the rotor of the MGU-H and there is a lot of inertia there. Several teams quickly realised that the energy triangle – battery, MGU-H, MGU-K – was heavily limited on the MGU-K-battery side, but not on the MGU-H. It was a lot of fun working out how to get energy from the MGU-K to the battery via the MGU-H.'

The answer was to harness the inertia in the turbo. 'You spin the turbo up using energy from the MGU-K, then brake it, feeding the energy back to the battery, then repeating the process very quickly.'

The result being the limitations on energy transfer are bypassed.

'I think pretty much everyone uses that approach nowadays. It shows you how racers think, how we try and get around the sporting rules by using technical capabilities.'

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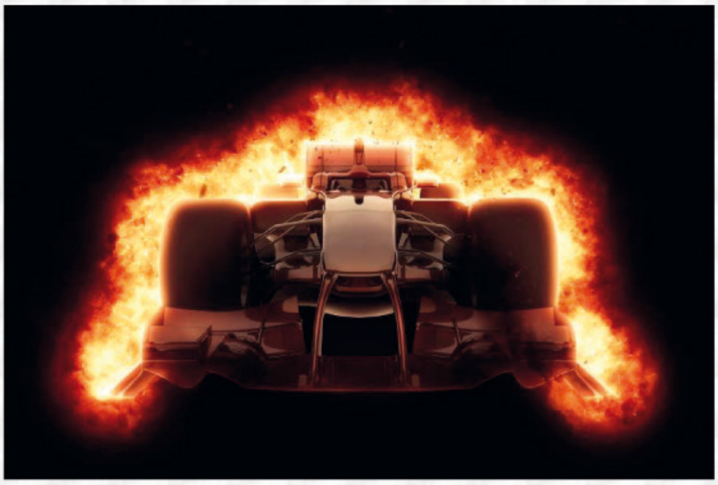

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Understanding the torque and power sensitivities of each sector of a track is key to making best use of the available energy

XPB

rules are written, this can be fed directly to the MGU-K. The result being that over a lap, there is far more than the regulation defined 2MJ of energy available to drive the MGU-K at its maximum 120kW.

Understanding just how powerful a tool the MGU-H was took some teams longer to figure out than others.

'People began to learn how to optimise the turbos, because they weren't just turbochargers, they were turbo generators,' recalls McDonald-Walker. 'It's all about a holistic approach. It's vitally important that you think about the whole picture of how the energy is being used. With the MGU-H, when you're controlling the boost by grabbing the shaft, and all that power, up to 100kW is going into the MGU-K, you are in essence electrically turbo compounding. This is why MGU-H is so beautiful.'

However, past a certain point on a straight, the benefit of adding the extra 120kW of the MGU-K will start to reduce. Then, notes McDonald-Walker, 'you can start compounding into the battery until you reach the point for lift and coast and then braking, at which point you start again.'

Attack mode

The processes described up until now apply to a 'normal' racing lap, where a driver is trying to hit a certain delta. But what would the energy management profile look like on a full attack lap, during qualifying, or when trying to take a position?

'You throw everything at the MGU-H and everything the MGU-K has on the way out of the corner up to your traction limit, as per a regular lap,' highlights McDonald-Walker. 'But then as you leave the traction-limited phase and move off down the straight, you'll do something slightly different.'

That's because in full attack mode, there is no need for energy or fuel saving.

'You want everything available. You'll probably lift the knock limit on the engine, with a greater number of allowable knock events per 1000 revolutions, raising the performance allowed from the engine. But you will do some clever stuff with the ERS, too.

'All of the available battery energy fires into the MGU-K to the limit of the power that you're allowed. You would also hit the MGU-H with all the power you can.'

So why would this be beneficial? McDonald-Walker explains: 'You can open the wastegate completely and then run it like an E-turbo. Supplying all of the compressor power – 90-100kW – straight from the MGU-H, so all of the exhaust energy is just bypassing the turbine and going straight out the back. It's a huge waste of energy, but it makes a significant reduction in exhaust back pressure.

'That, coupled with the MGU-K deploying at full power, means you are getting everything you can from the power unit. With the 100kW to the MGU-H and 120kW from the MGU-K (which is closer to 130kW at the battery) that is nearly 250kW being pulled from a tiny little battery.'

The exact strategy for the deployment of these processes throughout a race very much depends on the tactical situation a driver is faced with. It is here that simulation comes into play, with accurate modelling of the powertrain and overall car key to performance optimisation. However, that is a subject on its own and will have to be left for part two of this overview.

> 'It's all about a holistic approach. It's vitally important that you think about the whole picture of how the energy is being used'
>
> *Ruaraidh McDonald-Walker, technical director at McLaren Applied*

Driver workload

Hybrid racecars are complex beasts, and modern drivers are required to operate far more complicated systems that their forebears. However, McDonald-Walker notes that very early on in the Formula 1 hybrid era, it became clear that minimising this complexity was important.

'It was probably around 2013 that we worked it out. The driver doesn't really care about the MGU-K, MGU-H or anything else, they just want to go fast or slow, save energy or use energy.'

Formula 1 engineers were not the first to learn this lesson, and there is a parallel to be drawn with WW2 fighter aircraft design, as detailed in Callum Douglas' excellent tome on piston engine fighter development, *The secret horsepower race*.

'In a Spitfire, the pilot had to handle mixture control, the throttle which controls boost and then the prop pitch control. The pilot had to juggle all of those, plus the rudder trim, and fly the thing, and occasionally shoot at something else.

'On the other side, you had the Focke-Wulf 190, where the pilot has just one big lever to fast or slow.' That lever controlled the *kommandogerat*, in effect a mechanical engine control unit, which worked out the fuelling, prop pitch and ignition advance for the pilot.

'All the pilot had to think about was go fast to kill or slow to cruise. The same is true in the hybrid Formula 1-era cars.'

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Applied science

Putting the damper workbook to the test

By DANNY NOWLAN

Fig 1: Scorch Racing Silvia S15 Time Attack Challenge racer

One of the most popular articles I have ever written for *Racecar Engineering*, and one of the most downloaded items on the ChassisSim website, is the damper workbook. Not only does that tell me this is a hot topic, but it also shows there is a lack of genuine information out there on this important matter of racecar tuning.

There's also a common theme I see with racecar damping discussions, and that's over complicating things when they don't need to be. So, what we'll be doing in this article is applying the knowledge we already have and showing how simulation tools entered the equation on a car I recently worked on.

The car, shown in **figure 1** is the Scorch Racing Silvia S15 Time Attack car raced by Tominoko 'Under' Suzuki in the World Time Attack Challenge Pro class at Eastern Creek Raceway in Australia.

This car is a fire-breathing monster. We are talking 900bhp and C_{LA} numbers well north of seven. If you put DTM slicks on this thing, over the course of a lap it would make most circuit cars look rather modest, yet it's still a formidable performer with the halfway house tyres it wears, which are a cross between a performance road tyre and a racing slick. Consequently, this car offers us a great case study of just how effective the approach I will cover here can be.

The other thing to consider is that the way the initial damping curves were deduced for this car used nothing more complicated than high school maths. Simulation software then took us the rest of the way. This is a perfect example of how you use simulation properly, rather than hoping it is going be some sort of magic wand.

Starting point

As always, our start point is the quarter car model, as illustrated in **figure 2**.

This is the most basic building block of racecar damper analysis. Yes, it is simple and, in order to use it, you cut corners by assuming the body rate is less than the tyre spring rate.

The way the initial damping curves were deduced for this car used nothing more complicated than high school maths

Fig 2: The quarter car model

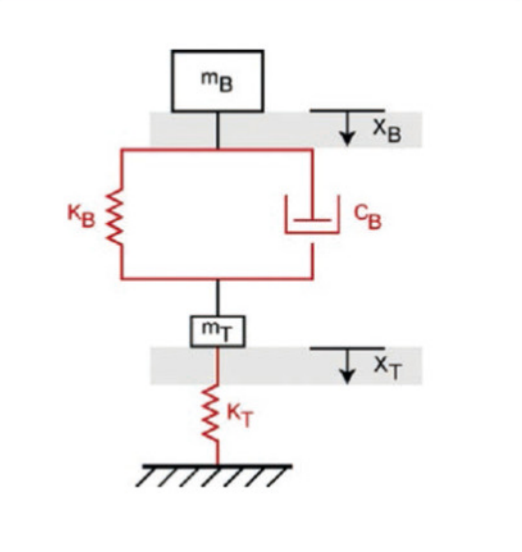
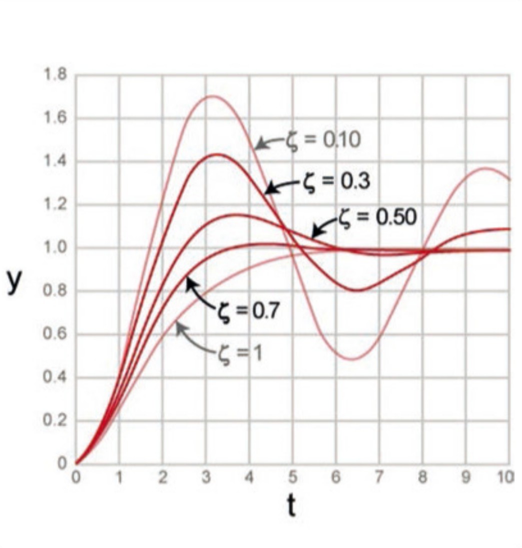


Fig 3: Second order system response



This assumption leaves a lot to be desired for high downforce cars because of the high spring rates you need to hold the car up. However, the power of the quarter car model is exactly that simplicity and, when used intelligently, is still a very useful tool.

I have covered the derivation of this in previous articles, but **equations 1** and **2** need committing to memory.

$$\omega_0 = \sqrt{\frac{K_B}{m_B}}$$

$$C_B = 2\cdot\omega_0\cdot m_B\cdot\zeta \qquad (1)$$

$$\zeta = \frac{C_B}{2\cdot\omega_0\cdot m_B} \qquad (2)$$

Where,

ω_0 = natural frequency in rad/s
K_B = spring rate of the quarter car in N/m
m_B = quarter car mass in kg
ζ = damping ratio
C_B = damping rate in N/m/s

There are a couple of traps to avoid here. Firstly, all the wheel and damping rates are wheel rates. We'll chat about what they look like at the damper shortly. Also please ensure you work this in strict SI / metric units. I know this annoys some of my American readers, but I'm sure you'll get over it.

Now, there is one thing to note about what we have done with the quarter car model. The equations here effectively treat the tyre spring as infinite and approximate the car as a simple spring damper unit at the sprung mass. While this is not theoretically correct, it's a very good approximation for road cars and will get you started with a high-downforce racecar.

Also, because this is so numerically simple, it gives you a quantitative basis to start talking about your damping. As we are about to discuss, this is very effective, and takes you into a larger and more precise world.

Second response

The next step in this process is to understand what you want the damping ratio to do. For this, we need to consider a typical second order system response, as shown in **figure 3**. (Incidentally, the curve presented here comes from D'Azzo and Houpis, *Linear Systems Control Analysis and Design*, the go-to textbook for aerospace and electrical engineers designing flight controls).

The reason the second order damping response is so important is because it closely resembles the quarter car vehicle model. So, when the damping ratios are quite low – at about 0.3 to 0.4 – we have a lot of oscillatory behaviour. Not great for body control but very good for riding bumps.

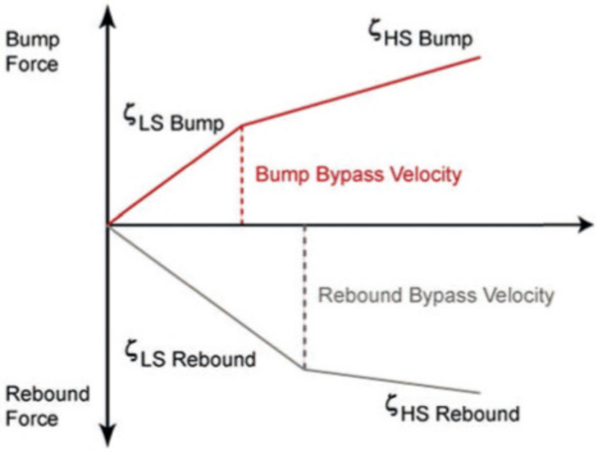
However, with damping ratios greater than 0.5, the damping response is quite good, which is bad for bumps but great for body control. If you can understand these two principles, you are well on your way to specifying a damper curve.

These guiding principles about bumps, body control and damping ratios then segue neatly into the damper selection guide, presented in **figure 4**.

For low-speed damping, body control is paramount. For mechanical cars we are talking damping ratios of 0.7, and for high-downforce cars we mean damping ratios of at least one. My hard limit is 1.4, but you get the idea.

Fig 4: Damper selection guide

Region	Value
$\zeta_{LS-Bump}$	This is body control so, if it is a bumpy circuit the ratio is 0.5. If the circuit is smooth choose 0.7. If the tyres need to be worked hard then choose 1.2.
$\zeta_{LS-Rebound}$	This will be dependant on a number of factors. Where body control is not significant use 0.3. However where body control is significant use 0.5 to 0.7.
$\zeta_{HS-Bump}$ $\zeta_{HS-Rebound}$	This is the high pass area of the damping curve. The values here should be 0.3 to 0.4



In low-speed rebound for mechanical cars, we are talking damping ratios of 0.4-0.5, while for high-downforce cars you are looking at damping ratios of 0.7. There is an outlier on this, but I'll discuss this at length in another article in the future.

With these guiding principles, let's use an example to show how you work out the damping rates and put together a damper curve. To begin, let's consider the quarter car parameters shown in **table 1**.

Table 1: Quarter car parameters

Parameters	Value
Quarter car mass	250kg
Motion ratio	0.8
Base spring rate at damper	300N/mm

Now we have these, we can use **equation 3** to figure out the natural frequency.

$$\begin{aligned}\omega &= \sqrt{\frac{K}{m}}\\ &= \sqrt{\frac{MR \cdot MR \cdot K}{m}}\\ &= \sqrt{\frac{0.8 \cdot 0.8 \cdot 300 \times 10^{3}}{250}}\\ &= 27.7rad/s = 4.41Hz\end{aligned} \tag{3}$$

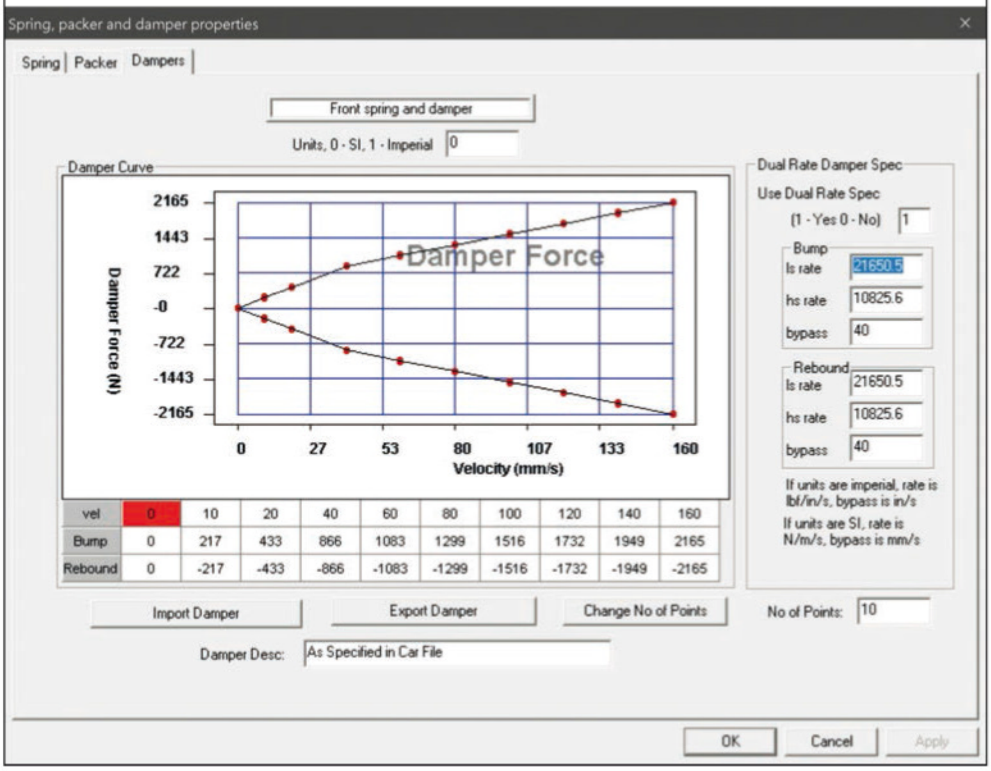
After we have done that, we can work out the base damping rate. This is called C_{BR} and is shown by **equation 4**.

$$\begin{aligned}C_{BR} &= 2 \cdot m \cdot \omega_0\\ &= 2 \cdot 250 \cdot 27.7\\ &= 13856.4N/m/s\end{aligned} \tag{4}$$

Now that we have the base damping rate, we can choose the actual damping we need. For the low-speed rates, we'll choose a damping ratio of one, and for the high-speed rates we'll use a damping ratio of 0.5. These can then be shown by **equation 5**, where C_{LS} and C_{HS} are the low and high-speed damping rates respectively.

$$\begin{aligned}C_{LS} &= C_{BR} \cdot \zeta_{LS}\\ &= 13856.4 \cdot 1\\ &= 13856.4N/m/s\\ C_{HS} &= C_{BR} \cdot \zeta_{HS}\\ &= 13856.4 \cdot 0.5\\ &= 6928.2N/m/s\end{aligned} \tag{5}$$

Fig 5: Entering a dual rate model in ChassisSim



Units, 0 - SI, 1 - Imperial: 0

vel	0	10	20	40	60	80	100	120	140	160
Bump	0	217	433	866	1083	1299	1516	1732	1949	2165
Rebound	0	-217	-433	-866	-1083	-1299	-1516	-1732	-1949	-2165

Dual Rate Damper Spec
Use Dual Rate Spec (1 - Yes 0 - No): 1
Bump
ls rate: 21650.5
hs rate: 10825.6
bypass: 40
Rebound
ls rate: 21650.5
hs rate: 10825.6
bypass: 40
If units are imperial, rate is lbf/in/s, bypass is in/s
If units are SI, rate is N/m/s, bypass is mm/s

No of Points: 10
Damper Desc: As Specified in Car File

The final step is working out the damper rates at the damper. To do this, all we need to do is to divide by the motion ratio squared, assuming the motion ratio is damper movement / wheel movement. Crunching the relevant numbers, we have what is shown in **equation 6**.

$$\begin{aligned}C_{D\_LS} &= \frac{C_{LS}}{MR^2}\\ &= \frac{13856.4}{0.8^2}\\ &= 21650.6N/m/s\\ C_{D\_HS} &= \frac{C_{HS}}{MR^2}\\ &= \frac{6928.2}{0.8^2}\\ &= 10825.2N/m/s\end{aligned} \tag{6}$$

At this stage of the game, you might be thinking this is all great, but how do we get a damper curve? Here's where the dual rate model in ChassisSim is about to become your best friend.

If you already have ChassisSim, all you have to do is click on the damper tab, choose the dual rate model and fill in the appropriate numbers. Then, when you press okay, you'll have that shown in **figure 5**.

When this process is done, you'll have a base damper curve, but it's not over yet, there is still work to be done.

The next step is to use the ChassisSim shaker rig toolbox. For a mechanical car, I'll usually focus on minimising contact patch load variation and then tune the frequency response. For a high-downforce car, the frequency response – and, in particular, minimising the cross-pitch mode – becomes dominant, because controlling the aero platform is your number one priority.

Key challenges

However, when this was applied to Suzuki's car, a number of key challenges where faced. Firstly, due to the nature of the car's tyres, you couldn't muscle it out with big main spring rates. That was a non-starter. Instead, significant support had to come from the third spring and, when you do this, you must factor this into the natural frequency and damper calculations we showed earlier.

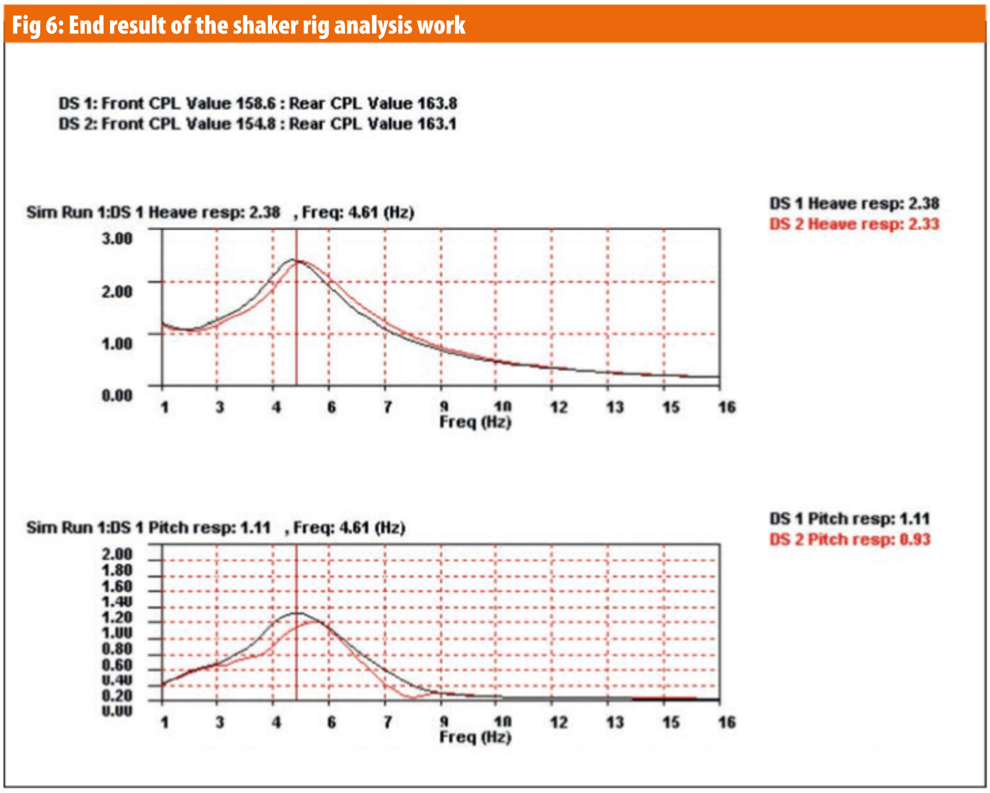
The other thing that made this job tricky is the car's high aero load. Combined with the nature of the tyres, both the aero response and the contact patch load variation became equally important.

What all this translated into was a lot of simulation work, the end results of which are shown in **figure 6**.

Here, the initial damper spec is black, and the final damper design is red. As can be seen, the contact patch load variation has dropped

For a high-downforce car, the frequency response becomes dominant, because controlling the aero platform is your number one priority

Fig 6: End result of the shaker rig analysis work



> **The real result here, however, was that all the mathematics translated into genuine on-track car performance**

by 4kg at the front and 0.8kg at the rear, while the cross-pitch mode response has dropped by nearly 20 per cent. This is about as close as you'll get to the Holy Grail and, if you see figures like this, you put them on the car.

When just that was done, to say Suzuki saw a step change in performance would be an understatement.

The net result is shown in **figure 7**.

Due to confidentiality, all scalings have been blanked out, but the traces are speed, throttle, steer and front and rear dampers, followed by longitudinal and lateral *g*.

In the low-speed section, the car's response is excellent, but there were still issues in the high-speed sections. I am pretty confident that was due to some matters being 'lost in translation', but this was resolved by going up in the high-speed damping.

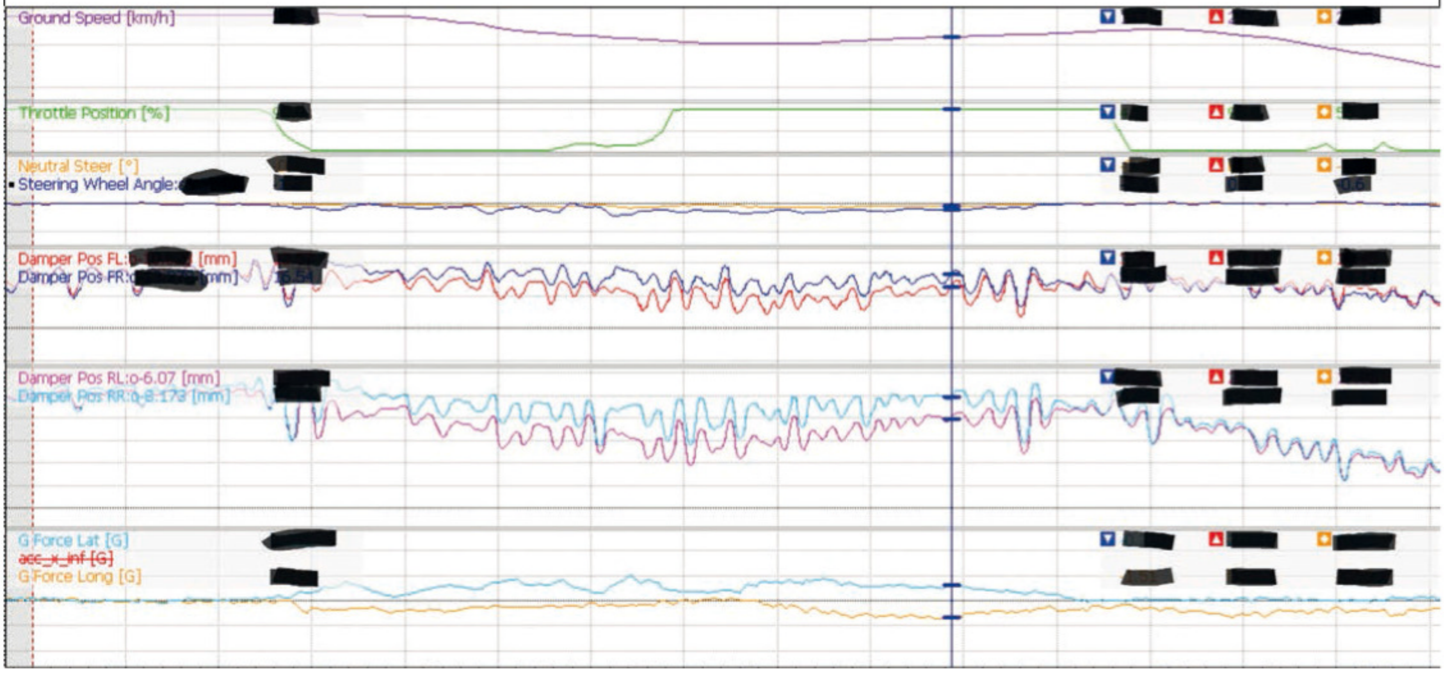
Key challenges

The real result here, however, was that all the mathematics translated into genuine on-track car performance. On worn tyres that where over 12 laps old, Suzuki recorded a lap time of 1:22.3s at Eastern Creek. What makes this all the more significant is that Pro class cars in Time Attack are brutal on their tyres. They are lucky if a set lasts for three laps. So, this kind of performance was unheard of.

Unfortunately, an accident in Thursday morning practice put Suzuki's car out of commission so it's true pace was yet to be seen, but there's absolutely no doubt it showed a distinct improvement and even greater promise.

In conclusion then, what we have just outlined is a very powerful, but also straightforward, technique, and a case study of how to tune dampers. While the method described is not perfect, it is practical, simple and will give you a feel for the numbers. Combine this with simulation, and use it as a calculator, not a magic wand, and the results will take care of themselves. The pace of Suzuki's car is proof positive it works.

Fig 7: Damper response at Eastern Creek after the recommended changes had been made



IN BRIEF

Kumho Tyre has been selected as the sole supplier to the **TCR World Tour**. The company's involvement with the TCR franchise started in 2022 in TCR Europe, Spain, Denmark and East of Europe series and has since increased to Australia, Brazil and Finland. Nine races have been selected for the tour, including Portugal, Belgium, Italy and Hungary, before moving to South America, Australia and Asia.

Korean tyre manufacturer, **Hankook**, had to shut down a production facility in Daejeon, 150km south of Seoul, after a fire destroyed around 400,000 tyres, including those intended for racing. 11 people were reported injured, and it took 13 hours to bring the blaze under control.

Hankook won the contract to supply tyres to the FIA Formula E series in 2022, the Super Taikyu Series in 2021 and also supplies tyres to the Lamborghini Super Trofeo series in Europe, North America and Asia. It is not yet known how these series will be affected by recent events.

Lamborghini has confirmed it will build a full racing engine for its LMDh programme, due to start next year, and will not transfer the engine to the new Huracan as was previously planned. Learnings will be carried over to the road car department, but the compromises needed to run a road car engine in the series were considered too great.

Silverstone Park's management team has been restructured. **Chris Kimber-Nickelson** has moved from development manager to commercial director, **Rachel Morris** will oversee investment management at the park, while **Ruth Williams** and **Rebecca Harrhy** complet the team in asset management and marketing.

Bosch, which supplies the MGUs to LMDh-class cars (GTP in the US), has signed a five-year partnership deal with IMSA to enhance vehicle performance, safety and create a more equitable and robust racing experience. All cars will now run with Bosch branding.

F1 tyre deal up for grabs

The three-year deal to supply Formula 1 with tyres for the 2025 season has been opened to tender by the FIA, with targets largely unchanged from the existing regulation set. The sole tyre supply deal also applies to Formula 2 and Formula 3, although the technical specifications for these series have yet to be defined.

Pirelli won the contract to supply Formula 1 in 2011, and since then has established a series of compounds to suit the needs of the heavy GP cars on aggressive track surfaces. Teams also have to run more than one compound during the race, forcing them to make pit stops.

'The targets set out in the tender will remain largely unchanged, with key characteristics remaining similar to the tyres currently in use,' says the FIA. 'These targets have been agreed through consultation with the commercial rights holders and the teams, and are designed to ensure a wide working range, minimise overheating and have low degradation, whilst also creating the possibility for variation in strategy.'

Formula 1 will continue with 18in tyres, having debuted the larger size in 2022, while the tender also requires interested parties supply an environmental impact analysis of the tyres used in F1.

All tyres for use in the series will have to run with RFID tags to make life easier for scrutineers.

XPB

Whichever company wins the new F1 tyre contract will also supply rubber for F2 and F3 as well

Geely launches new generation TCR

Geely Group Motorsport recently launched the new generation of its Lynk & Co Touring Car Racing (TCR) car, based on the refreshed 03 road car that was unveiled late in 2022.

The car has been engineered and constructed by Geely Group Motorsport and its subcontractors and features a re-designed front and rear, having been adapted for the hybrid system that will be implemented by the series in 2024.

Built to comply with all the latest FIA safety standards, including a new crash structure and rollcage, as well as an extrication hatch in the roof, the first cars will be delivered to Cyan Racing for the TCR World Tour programme, priced at €148,000 (approx. $160,000), as per the TCR cost cap regulations.

Described as a careful evolution of the original model, Geely's 03 car retains the company's 2.0-litre turbocharged motor, but a hybrid is coming

Low pressure, low blow

Michael Shank Racing, winner of the 24 Hours of Daytona for Acura, has been penalised for cheating, after being exposed for writing software code to send false tyre pressure information back to the series' engineering team.

The team has been allowed to keep its Daytona win (and the Rolex watches awarded to the winning drivers), but has been deducted points in both the Manufacturers' and Drivers' title standings, as well as receiving a fine of $50,000. Shank himself has been placed on probation until 30 June 2023.

IMSA has strict limits on minimum tyre pressures and maximum camber angles in order to protect the Michelin tyres as teams have in the past run settings that have led to tyre failures.

Michael L Levitt

MSR have been found guilty of manipulating tyre pressure data to mask the possibility of the team were running below the prescribed minimum

The governing body monitors those limits using live TPMS data, so is able to see when a team is running outside the prescribed limits. After a final sprint to the flag following a late yellow, the MSR Acura, driven by Tom Blomqvist, won the 24-hour race by just over four seconds over the Wayne Taylor Racing Acura.

However, subsequent investigations by Honda Performance Development and IMSA found the team was able to run lower than the permitted tyre pressures, and that there had been an intentional effort made by the team to mask the true data.

The team was consequently found in breach of article 3.6.6.D, which states, 'Intentional application of software offsets within the pressures being reported by the tyre pressure monitoring system and associated car telemetry system is prohibited and may be subject to penalty.'

IMSA's judgement, issued on Wednesday 8 March, ahead of the 12 Hours of Sebring race, went on to say, 'After completion of post-race technical inspection and both provisional and official results were released for the Rolex 24 at Daytona, IMSA became aware of the potential manipulation of tyre pressure data from the no.60 car to IMSA as the monitoring point for the minimum tyre pressure regulation.

'Following a thorough investigation of all cars in the class, IMSA officials today announced that the no.60 Meyer Shank Racing GTP team has been penalised.'

Acura then issued a statement, quoting HPD president and technical director, David Salters, who was instrumental in HPD's investigation of the cheat software.

'We are extremely disappointed in the misconduct of the Meyer Shank Racing (MSR) team during the Daytona race,' said Salters in the statement. 'We became aware of the problem with the data from the no.60 MSR car and, after detailed investigation following the race, we reported our findings to IMSA.

'HPD does not tolerate any misconduct, delinquency or data manipulation of any kind.'

Shank issued a statement in return, accepting responsibility, and saying that one team engineers has had his IMSA credential revoked and membership of IMSA indefinitely suspended.

'We have dealt with this issue internally and the team member that was responsible is no longer with the organisation,' read the MSR statement.

However, some questioned whether it was right to name and penalise just one team member, pointing to the fact that other team members will have set the tyre pressures before fitting them to the car.

Shank and his team competed at Sebring and will contest the remaining rounds of the series with Acura, while HPD refused to comment on whether or not it would take any further action against the errant team.

Team JOTA going for gold

Jota Sport

Resplendent in its new Hertz livery, Team JOTA's Porsche 963 is expected on track this April, in preparation for a full attack on the 2024 season

Team JOTA has unveiled its new Hertz Racing Gold livery for the Porsche 963, which will race at Le Mans and the remaining rounds of the FIA World Endurance Championship this season.

The team will take delivery of the car early in April, race it for the first time at Spa at the end of that month and then head to Le Mans in June. Sources at Team JOTA say it does not expect to challenge Porsche Penske Motorsport this season, but wants to accumulate race mileage ahead of a full assault next year.

Mustang on the loose at Sebring

With its M-Sport-tuned 5.0-litre, Coyote V8 on song, the new Ford Mustang GT3 car sounded incredible lapping around the old airfield in Florida

Ford's Mustang GT3 took to the track for the first time at Sebring in March, the initial step on its way to competition next year.

The car, developed by Ford's long-term partner in both production and racing, Multimatic, will be eligible to compete in the IMSA WeatherTech Sportscar series, as well as ACO and SRO-sanctioned events.

The Mustang proved to be controversial when it was first announced in that there was doubt cast over whether or not enough customer versions would be made available to fulfil the regulations.

At the initial announcement at Daytona in 2022, there was no confirmation of a racing programme beyond the US, with only a two-car, factory-backed team and 'customer Mustang racecars for the GTD class' mentioned.

However, since then, Ford has reassured regulators it will fulfil the minimum number of 20 cars sold to the market in the first two years of production, and committed to selling the car outside of the US.

Consequently, the Mustang is expected to race in different countries around the world. The car has yet to be officially presented but, as the car is eligible to race at Le Mans next year, alongside already confirmed races in the US such as the 24 Hours of Daytona, 12 Hours of Sebring, it is also likely to compete in the Intercontinental GT Challenge.

Powered by an M-Sport-tuned version of the production car's 5.0-litre, Coyote V8 engine, the car appeared at Sebring in the hands of factory driver, Joey Hand, during the week following the 12-hour race, where it was also joined by Corvette's 2024 GT3 car.

Formula Student UK partners Coryton

Formula Student UK, which is celebrating its 25th anniversary at this year's competition at Silverstone on 19-23 July, will offer sustainable fuel options for teams developing internal combustion vehicles.

Motorsport UK, the governing body for motorsport in the UK, has provided a grant for entrants to use Coryton sustainable fuels in ICE powertrains.

The fuels will offer an 80 per cent reduction in greenhouse gas emissions for the FS cars when compared to fossil fuel-based equivalents. It will also bring the competition in line with Motorsport UK's objectives to achieve greater sustainability across all motorsport series.

First announced during the 2022 finals event, teams running internal combustion vehicles will now have the chance to use one of two 100 per cent sustainable / non-fossil fuels – an E85 and a 95 RON E10 – as well as the standard 99 RON that has traditionally been provided. The sustainable fuels are second generation biofuels, made from agricultural, forestry and food processing waste. The carbon in the fuels is effectively recycled from the atmosphere, rather than additional CO_2 being released from fossil fuels.

'The 2023 Formula Student competition is a fantastic opportunity for the automotive and motorsport engineers of the future to experience and deploy leading-edge technologies in a stimulating motorsport scenario,' says Hugh Chambers, CEO of Motorsport UK. 'By funding the use of sustainable fuels for those teams that choose an internal combustion engine, we hope to inspire the next generation of engineers to have a broad view of the future technologies of propulsion.'

David Richardson, business development director at Coryton, said: 'We're delighted to be involved with Formula Student and to have the opportunity to showcase the potential of sustainable fuels when it comes to the continuation of the ICE. As we often say, the ICE in itself is not 'dirty', it's only the fossil fuels used within it. Sustainable fuels are here and ready now, and should be used alongside every available technology to help tackle climate change.

'Obviously, F1 and other motorsport organisations see the potential of sustainable fuels, and it's important that the next generation of engineers have the opportunity to be involved. We feel passionately about securing the future of automotive engineering at the grass roots level. Electric-only courses very much have their place but it's vital to show that mechanical engineering can also have a clean future ahead, too.'

While the number of university teams currently developing electric powertrain cars for the competition mirrors the same trend in the broader European automotive industry, the provision of these new sustainable fuels is part of Formula Student UK's commitment to support teams of students that are not able to make that change.

James Key departure

James Key has left McLaren as part of a team re-structure that sees a Technical Executive Committee installed in place of the more traditional single technical director role.

The new Technical Committee will see Peter Prodromou move into the role of technical director aerodynamics, David Sanchez returns to McLaren as technical director car concept and performance after a decade at Ferrari, while Neil Houldey becomes technical direcor engineering and design. Sanchez will not start at McLaren until 1 January 2024.

Further strengthening the size of the team, Giuseppe Pesce is the new director aerodynamics and chief of staff, while Piers Thynn is the F1 team's new chief operating officer.

'Looking ahead, I am determined and fully focussed on leading McLaren back to the front of the field,' said Andrea Stella, team principal.

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March madness

What's the difference between European and US racing?

The countdown to Le Mans began in March with the 12 Hours of Sebring, round two of the IMSA WeatherTech Sportscar series, and the opening round of the World Endurance Championship. If ever there were a more graphic illustration of the difference between US and European racing, I'd love to see it.

The WEC kicked off with an eight-hour, 1000-mile race on the Friday and, for at least the last seven hours, it was dominated by Toyota. The Toyota Gazoo Racing team, racing its second generation GR010 for the first time, won the race by two laps from the rest of the field. There were several factors behind this; the team could go further on a tank of fuel, faster on the second stint on the same tyres, benefited from the upgrade package it was allowed to introduce this season, and European regulations meant whatever advantage the team had would be protected to race end.

> **European regulations meant whatever advantage the team had would be protected to race end**

That did not lead to exciting racing. Although the two GR010s lapped closely, they were not fighting for the lead. In order to pass, the following driver must ask permission from the pit wall, which must be granted, and only then can the pass be made. It will be kept on the condition that a gap is created, demonstrating there is a performance advantage to running this way round. The erstwhile leading car also has to prove there is no performance advantage, and then asks for the place back. It's the only time the cars run flat out.

Red and raw

The only challenge to Toyota came from Ferrari. The new 499P was quick over a lap, and even over a stint. Starting from pole, the red cars had the raw pace but not over the double stint, required by series organisers who provide too few tyres to complete the race without doubling at some point. There were some mistakes made by the team in terms of strategy, but it was a good debut for the new cars.

It was noticeable that the Ferraris out raced the likes of Porsche and Cadillac, both of which had competed at the 24 Hours of Daytona in January, and had also tested at Sebring. The 499Ps also out raced Peugeot, who had a shocking weekend. The cars were slow, unreliable and finished up propping up the results sheets.

Sebring was never going to be the best weekend for the French team as it was the only one not to have tested at the Florida track in the off season but, in front of Stellantis Group CEO, Carlos Tavares, it was a weekend to forget.

By contrast, the IMSA style of racing made for a spectacular, if messy, ending. The 12-hour race normally features safety cars that bunch up the field, and with the wave-by teams are easily able to make up lost laps and time lost through strategy. Any advantage is therefore wiped out, which means there is often a sprint to the flag.

While some consider this unfair, others point to the excitement offered by Saturday's race compared to Friday's.

It is true that much of the IMSA race was spent waiting for those final moments but, with fewer tyres allocated than were required to complete the 12-hour race, like their WEC counterparts, the prototype teams were also forced to double stint, but all did so in the heat of the day, knowing any time lost would be recouped at the next yellow.

It makes a mockery of the idea of using fewer tyres, as teams stored as many as they needed for the sprint. As temps dropped, and with fresh tyres at every stop, the second half of the race was quicker than the first.

But then it happened.

The three leaders, all performance balanced and running close following a safety car, came upon traffic with 20 minutes remaining. The LMDh cars are heavier than their predecessors and drivers find it harder to overtake, so track position is more important than before. Mathieu Jaminet, leading in the Porsche but slowed by traffic, eventually found a gap and went for it, apparently not considering Felipe Albuquerque might make the same move in his Acura from second. The pair made contact, Albuquerque went off, hit a wall, came back onto the track and wiped out Jaminet's Porsche. Felipe Nasr's Porsche then became involved when he was hit from behind, allowing fourth-placed Jack Aitken in the Cadillac through to take the win.

It was a dramatic, if ignominious, end to a motor race.

Ill feeling

Finally, a hot topic in the Sebring paddock was the penalty awarded to the Meyer Shank Racing team at Daytona. Deliberately manipulating tyre pressure data sent to race organisers cost the team points in the championship, and an engineer his job. However, few believed it was the work of one individual, or that they should have been named in public, and most felt the team should have been stripped of its Daytona victory, and the £15,000 watches given to each of the winning drivers. That wound will take time to heal.

ANDREW COTTON Editor

Inside the world of modern motorsport technology
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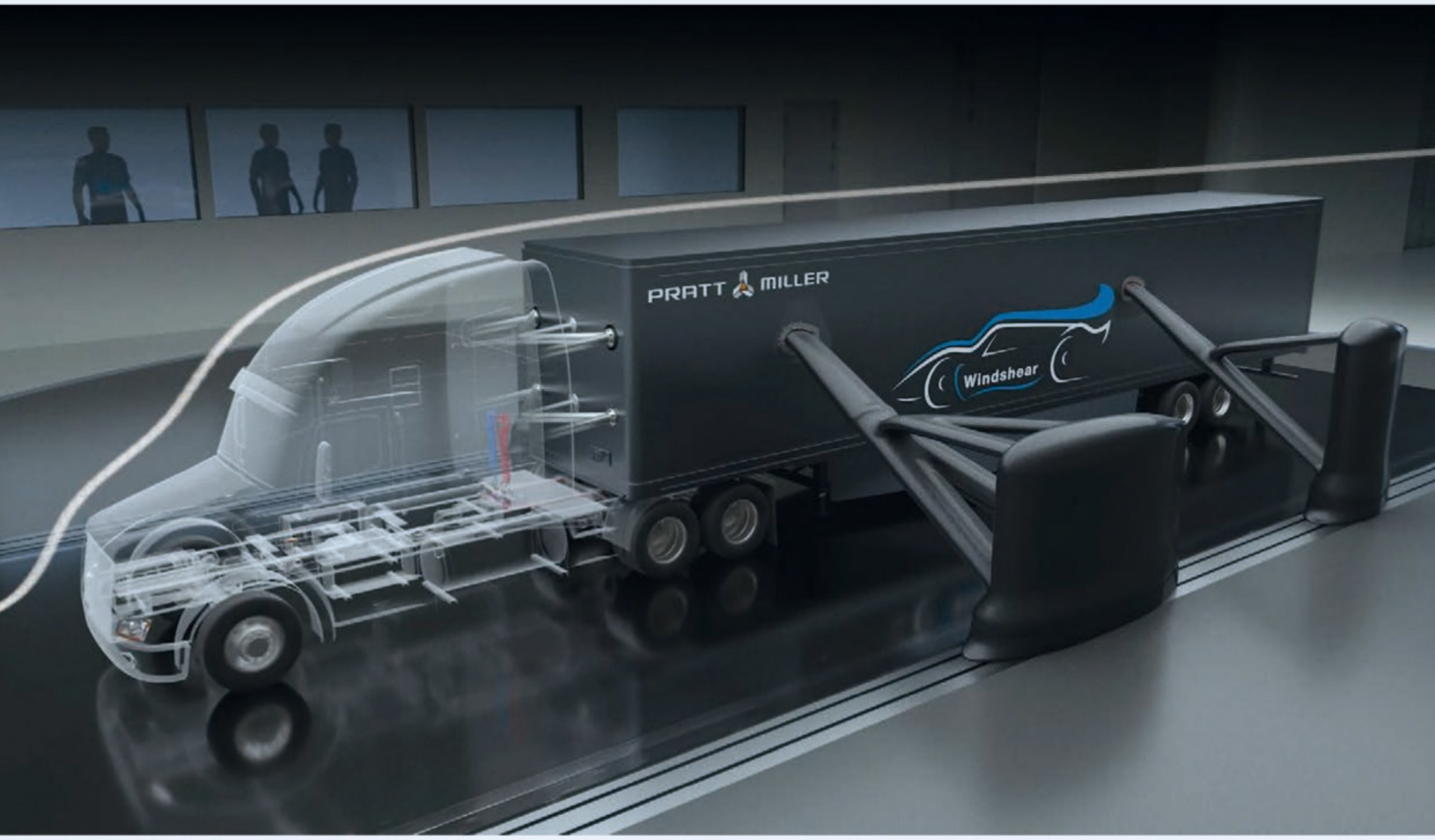

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